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VOL. X

ILLUSTRATED

BY

CALVIN F. SWINGLE, M. E.

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LESSON 30.

POWER HOUSES—SUB-STATIONS.

Power Houses.

The power houses or generating stations of our electric traction systems are nearly all A. C. installations. This is because the transmission to the trains is done by all alternating or partly alternating and partly direct current. Thus it happens that though trains may be operated A. C., D. C., or both, the power house is generally an A. C. plant.

Perhaps the greatest difference between the plants serving the electric divisions of our steam roads, and those of the large city systems is size. The city system plant is apt to be the larger. This occurs because railroads prefer to have several plants strung along the line so that no point of line shall be too far from a station. The city systems operating a network of tracks all fairly near the station, usually rely on one or two big plants.

Another reason is that steam roads coming into electrical operation at recent dates have taken advantage of the steam turbine, which will make a smaller plant for same capacity.

Figure 241 shows the comparatize size of the 5000-K. W. engine-alternator and 5000-K. W. turbine-alternator, both of which are installed in the Interborough Railroad plant in New York.

The large marine engine type, using the revolving element of the dynamo as part or all of its flywheel, seems the favorite engine unit.

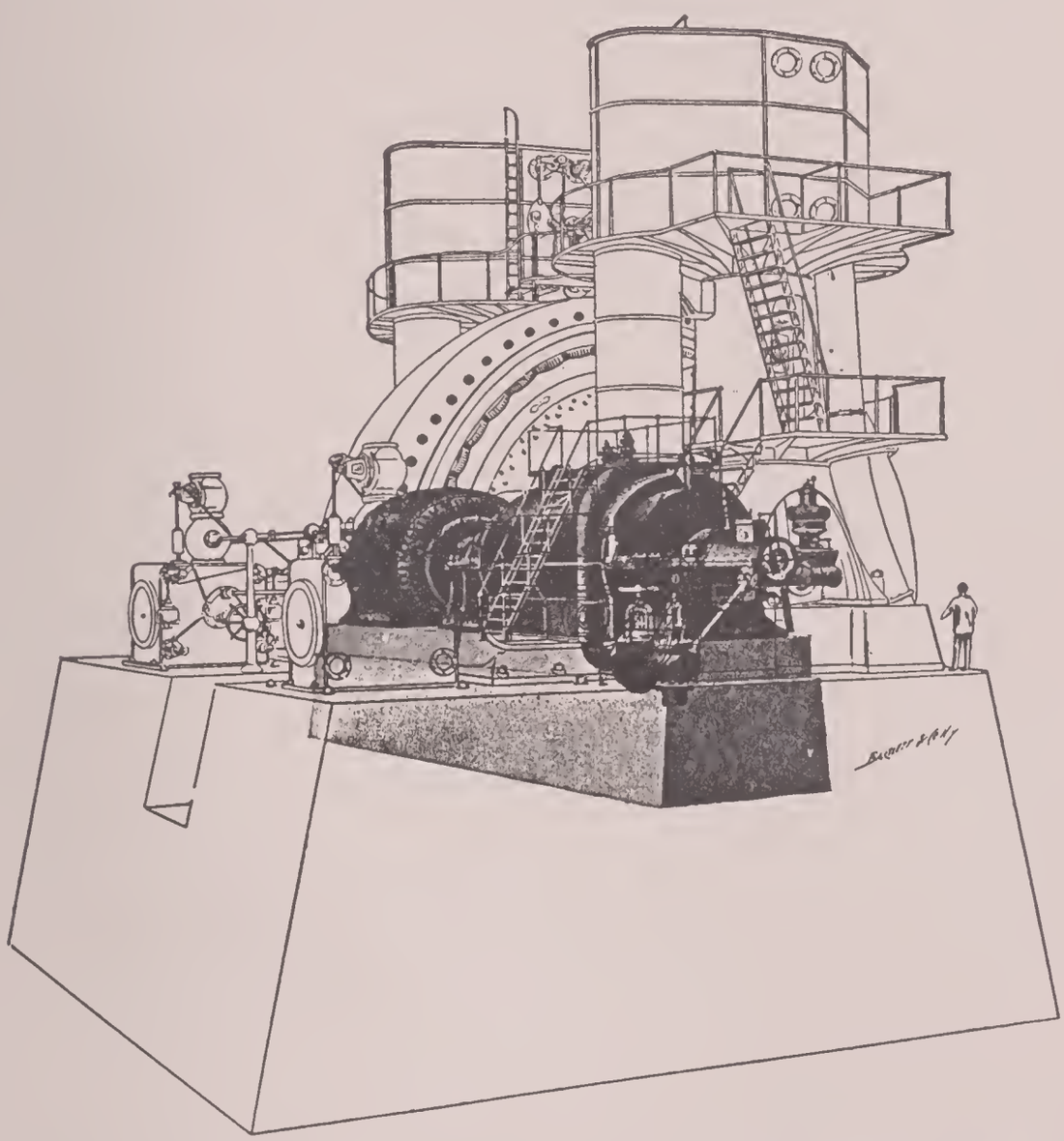


Fig. 241. Comparison of Space Occupied by same Kilowatts of Engine and Turbine Unit.

Figure 242 shows a 2500-K. W., 600-volt D. C. generator in the plant of the Providence, R. I., city system. Its actual size can be judged by height of the hand railing around the pit.

The Interborough plants in New York are both large. Fig. 243 shows the set of 5000 K. W., 11,000 volts, 263 ampere, 25 cycle, 3 phase alternators run by 7500 H. P. marine type engines at 75 revolutions per minute. These

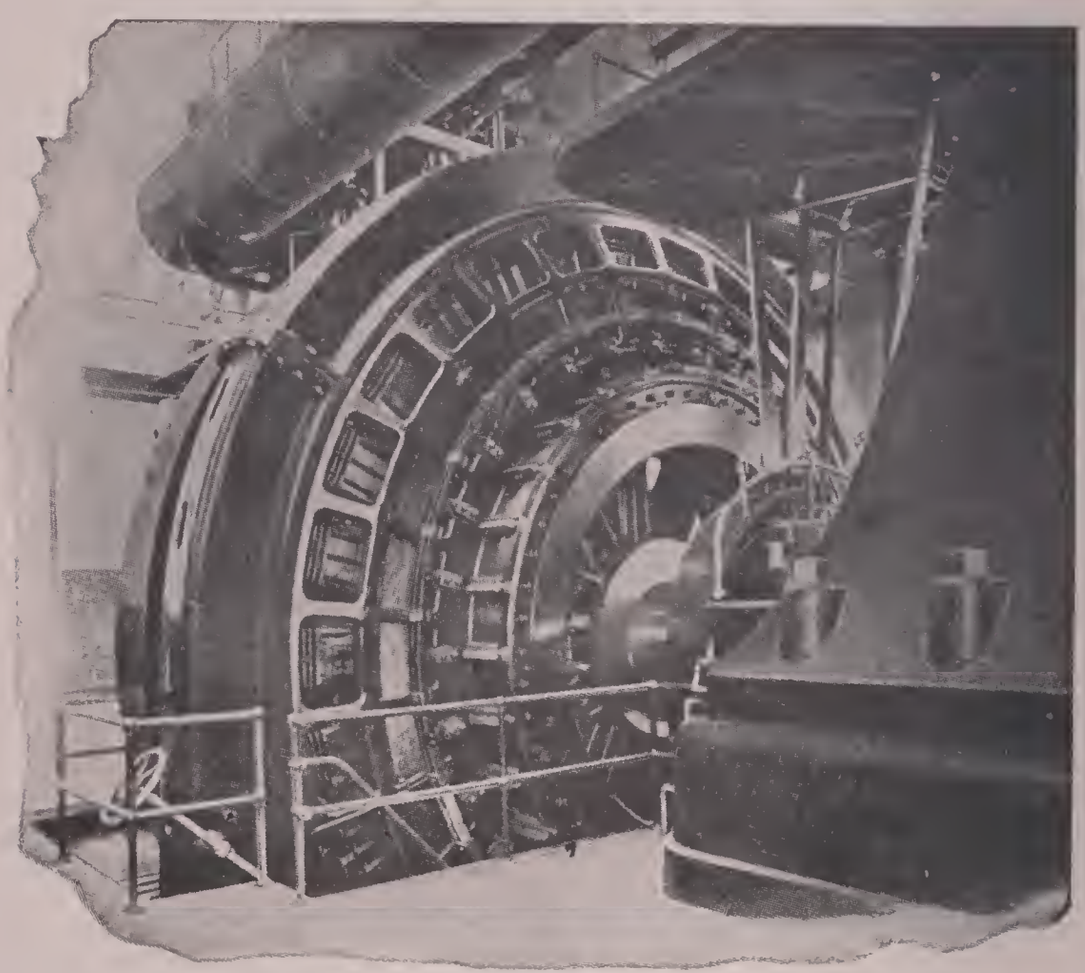


Fig. 242. Engine Generator of 2,500 K. W.

are in the 59th Street plant. The same type of generator is installed in the 74th Street plant. A view in the latter plant (Fig. 244) shows the rear of the same kind of machine as shown in Fig. 243.

The typical turbine-generator plant is shown in Fig. 245. While machines of this illustration are small capacity (400 K. W.) the lowness of the ceiling is well shown.

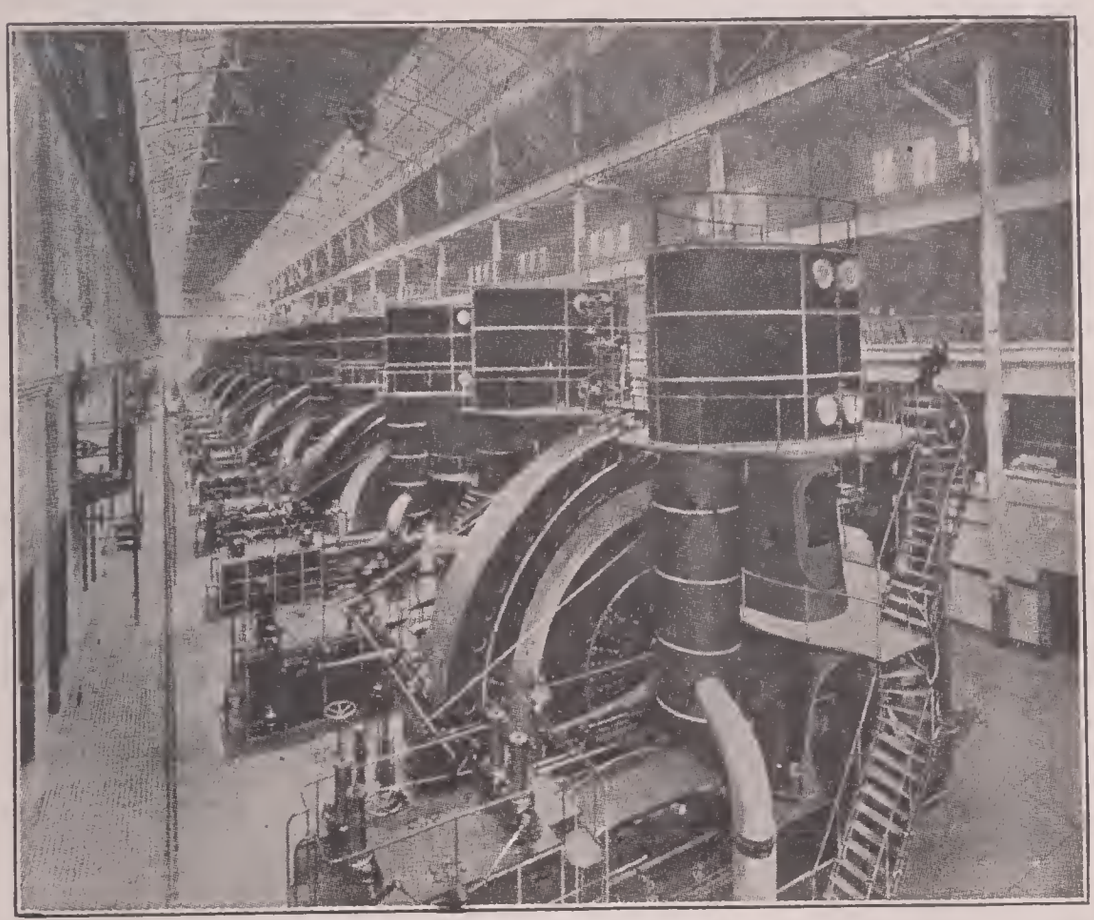


Fig. 243. Set of 5,000 K. W. Engine Alternators, Interborough Plant, New York.

Figure 246 shows a turbine unit of larger size.

Figure 247 shows another turbine plant and Fig. 248 is a view of a turbine unit installed along side of an engine unit.

Turbine Generators.

A 1500 K. W. turbine unit is shown in Fig. 249, and one with a 7500 H. P. turbine and 5000 K. W. alternator is shown in Fig. 250.

Fig. 244. Rear view of same kind of Machines as Fig. 243. Interborough Plant, New York.

The stationary armatures of such units are similar to the engine type, but are small in diameter and longer. Fig. 251 shows armature of a 1000 K. W., 2400 volt, 2 phase unit, while Fig. 252 shows an armature of a sim-

ilar machine wound for 5000 volts. Viewed from the interior the armature cores of Fig. 251 look like Fig. 253.

Owing to the high rate of speed at which a turbine revolves the revolving field is made bi-polar. The one in Fig. 254 has the lower coils in place, but the upper

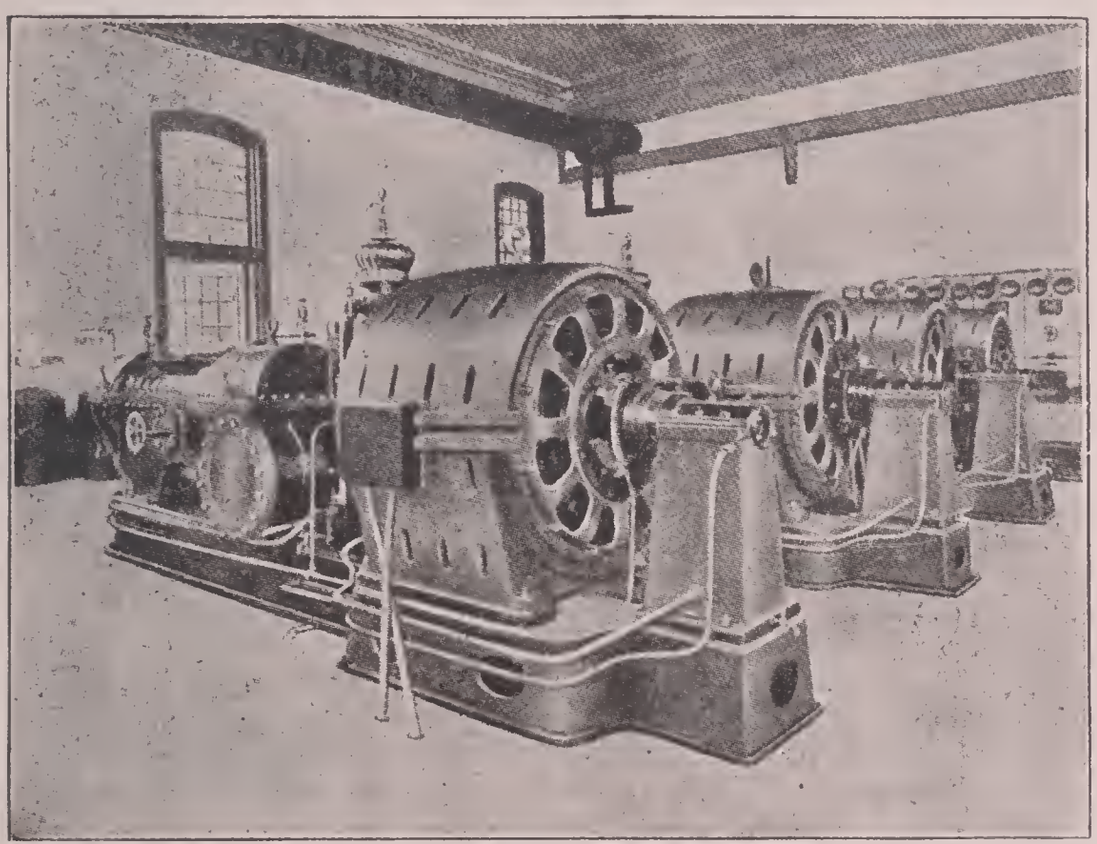


Fig. 245. Plant of 400 K. W. Turbine Alternators.

half is not yet wound. These two coils make the field core a large magnet with opposite polarities at top and bottom.

The core of a 6000 K. W. revolving field is shown in Fig. 255 to give an idea of its size.

Beside the large units just described the small turbine generators are very much used.

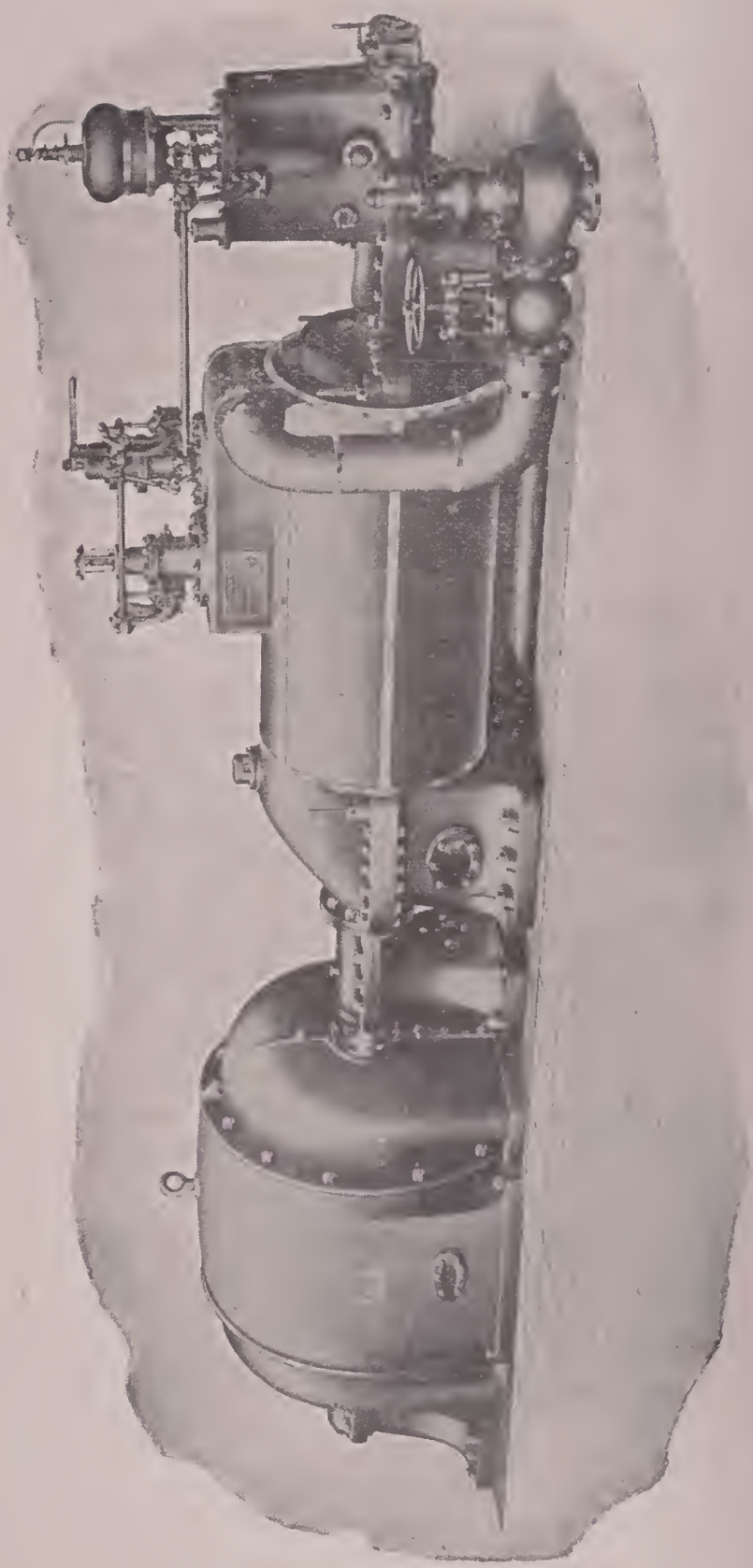


Fig. 246. Turbine-Generator.

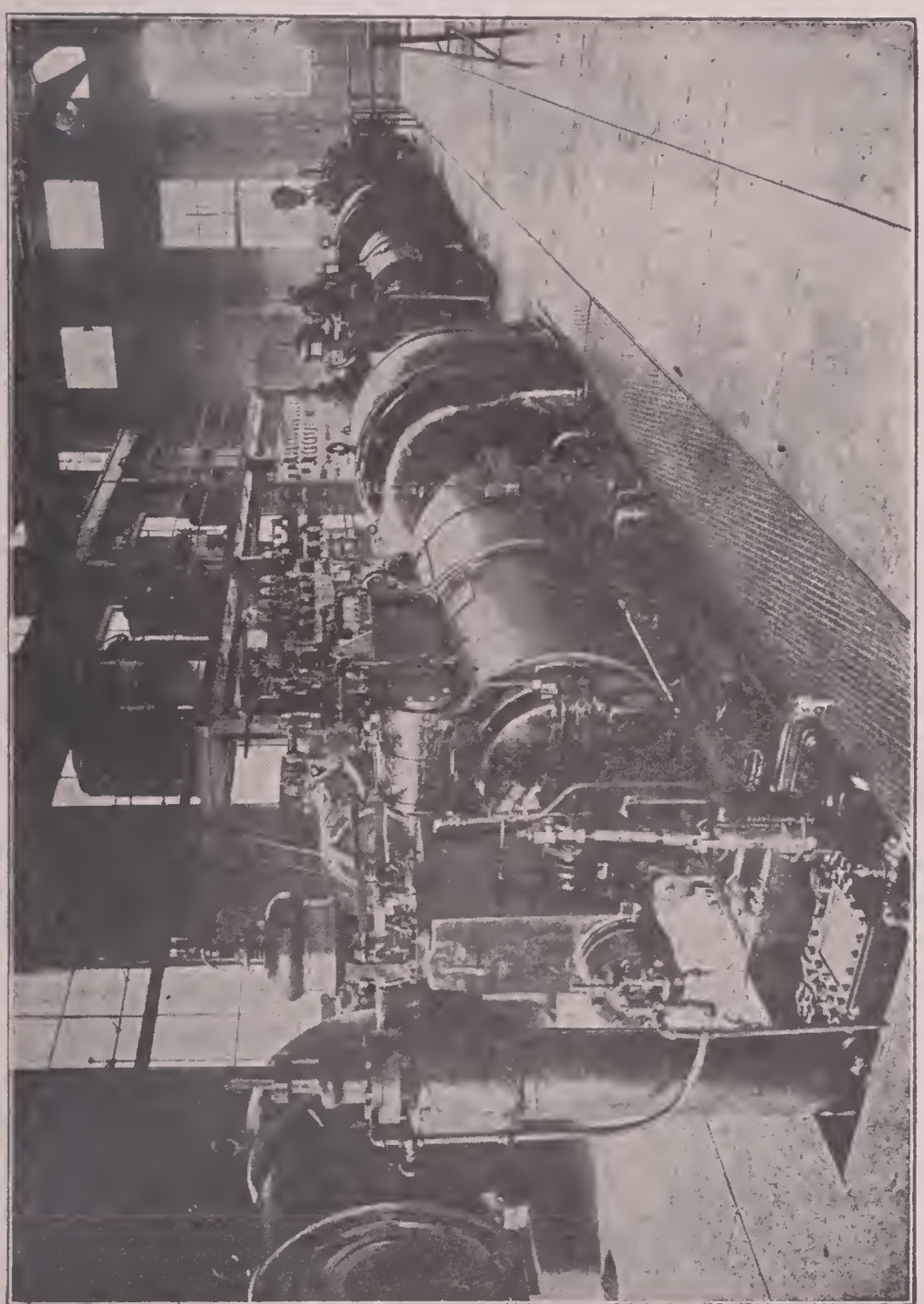


Fig. 247. A Typical Railway Turbine-Generator Plant.

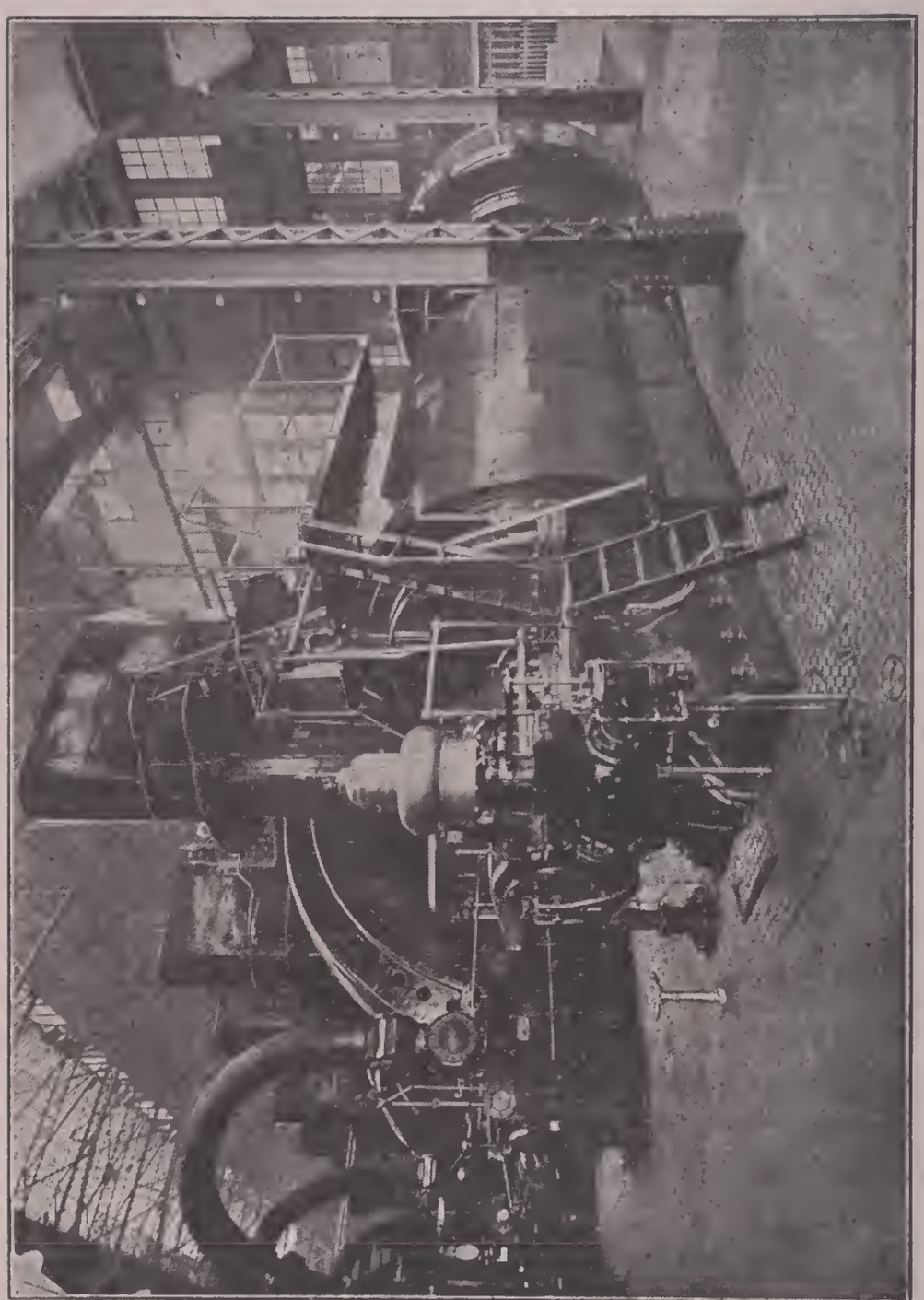


Fig. 248. 5,000 K. W. Turbine-Generator in Interborough Plant among 5,000 K. W. Engine-Generators.

The little 15 K. W. units of Fig. 256 are installed in baggage cars for train lighting, and when protected by a weather proof casing, as in Fig. 257, are installed on locomotives as shown in Fig. 258.

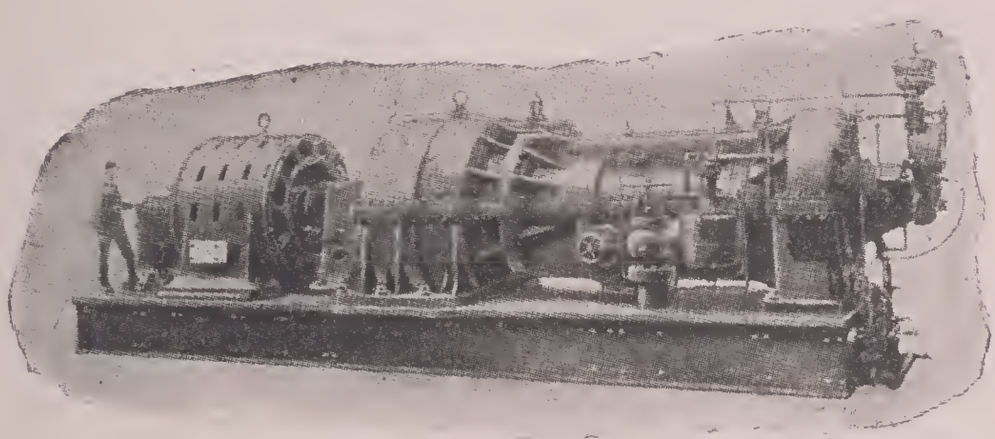


Fig. 249. 1,500 K. W. Turbine-Alternator.

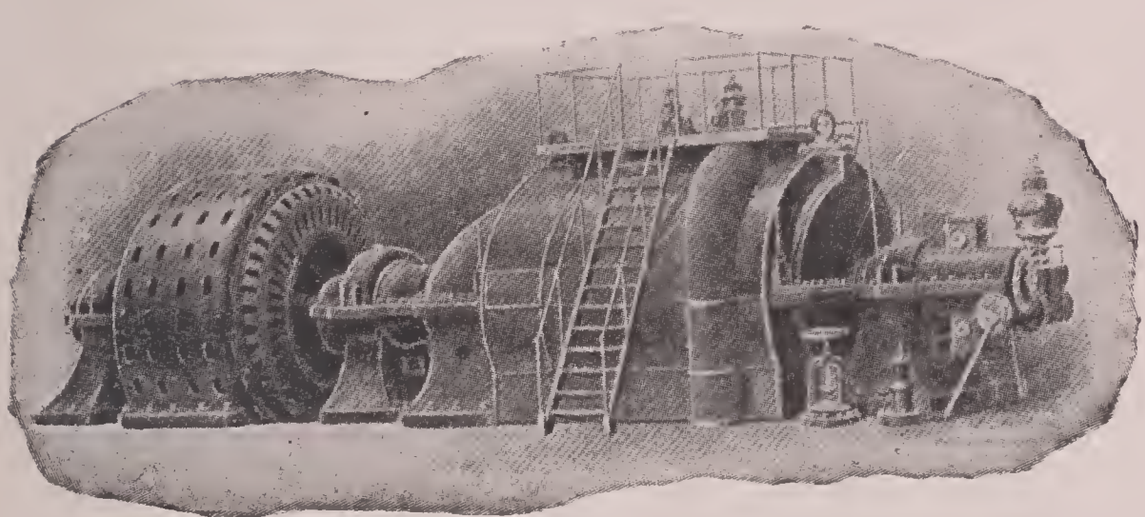


Fig. 250. 7,500 H. P. Turbine and 5,000 K. W. Alternator.

The motion of a turbine is given to the rotating parts by jets of steam blowing against vanes, in much the same way as a water turbine using a very high head of water.

Their value lies in the high rate of speed, no reciprocating parts, ability to work with as high a vacuum as the condenser pumps can furnish, and the small space occupied in comparison with engine units.

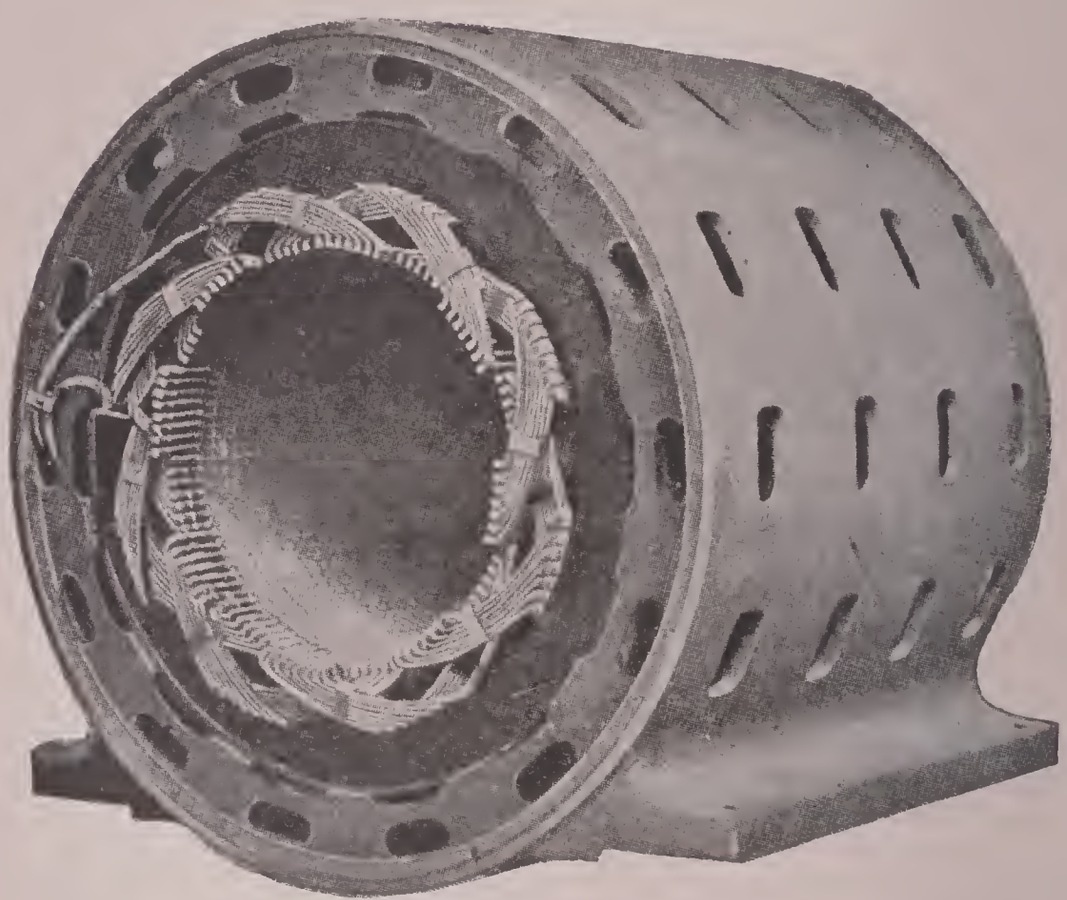


Fig. 251. Stationary Armature of 2,400 volt Turbine-Alternator.

SUB-STATIONS.

The sub-station, the link between the transmission line and the trolley wire or third rail, is a thing we would like to eliminate.

It is an extra building with costly apparatus, needing skilled attendance.

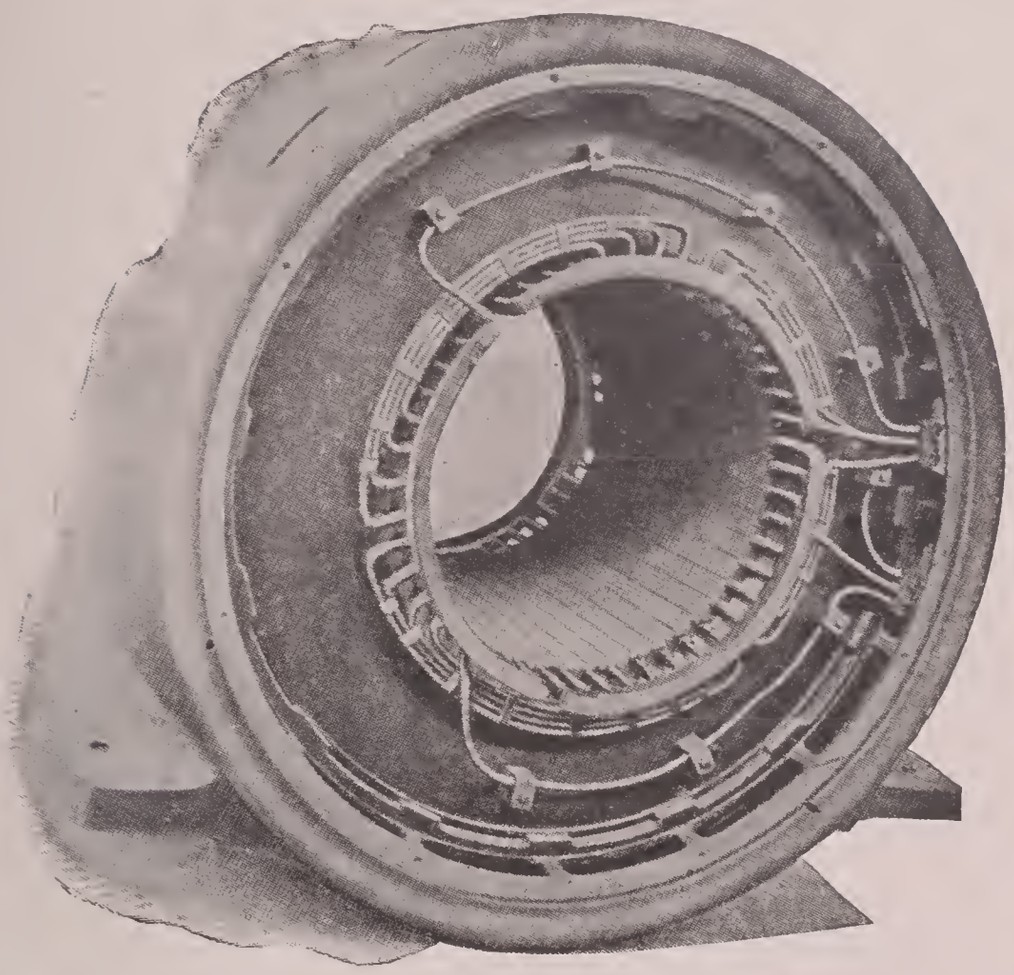


Fig. 252. Stationary Armature of 5,000 volt Turbine-Alternator.

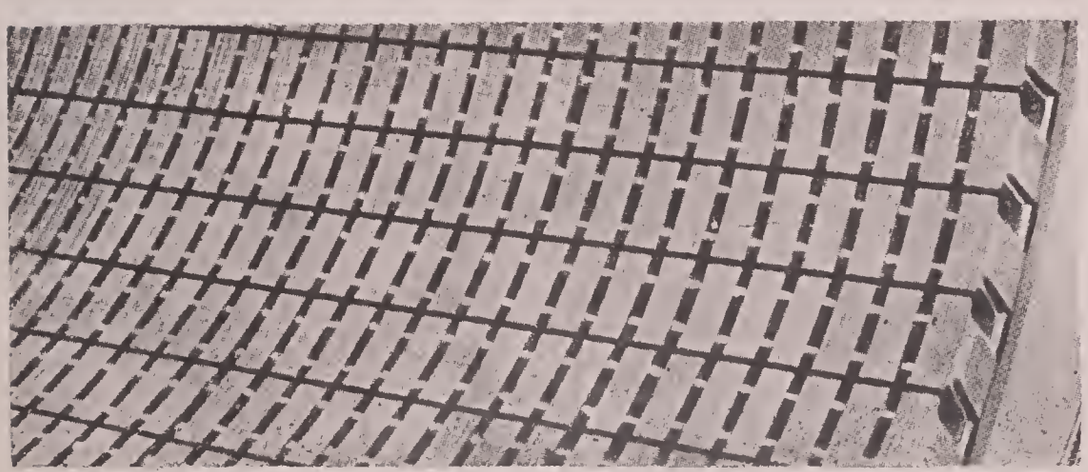


Fig. 253. Interior View of Armature Core of Fig. 251.

With A. C. generation and D. C. utilization of power the sub-station with its rotary converters is a necessity. Where A. C is used straight through the sub-station may be omitted, by having each station fed directly, with a very high tension trolley wire.

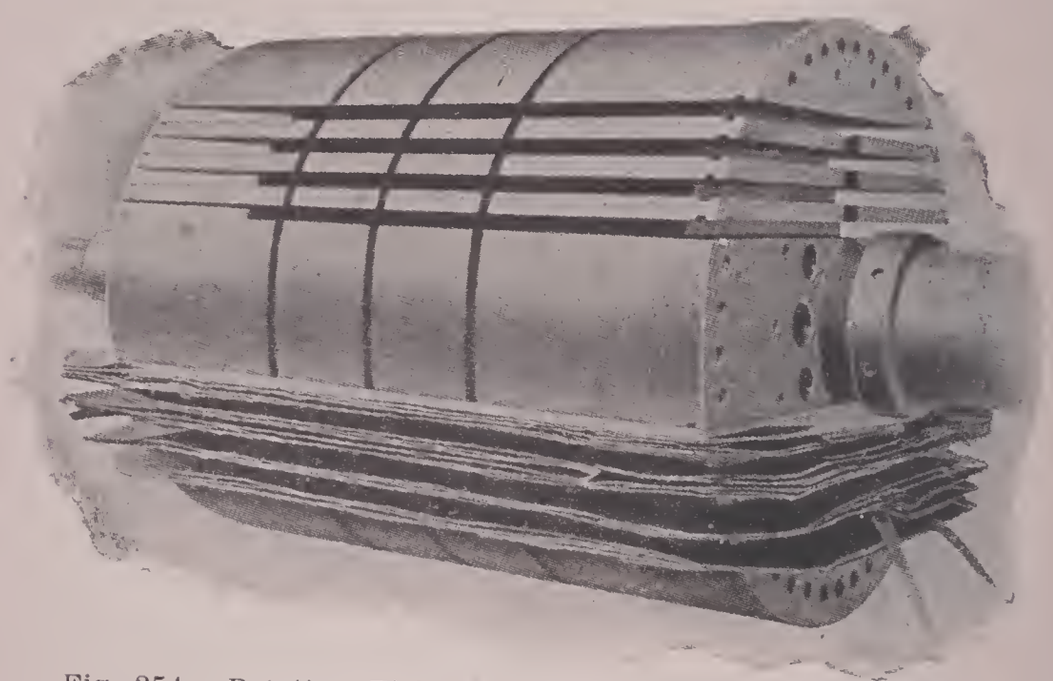


Fig. 254. Rotating Field of Turbine Generator, half wound.

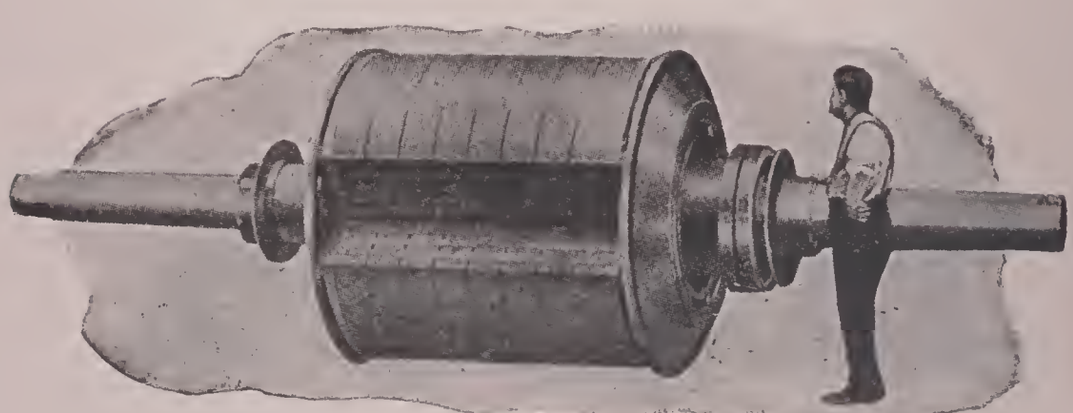


Fig. 255. Rotating Field of 6,000 K. W. Turbine-Generator.

Usually there will be sub-stations containing only transformers. The 22,000 volt lines will feed these transformers and they will feed the line with some lower

voltage. The scheme of placing costly gnerators directly on line, running the danger of static and lightning discharges, seems rather rash.

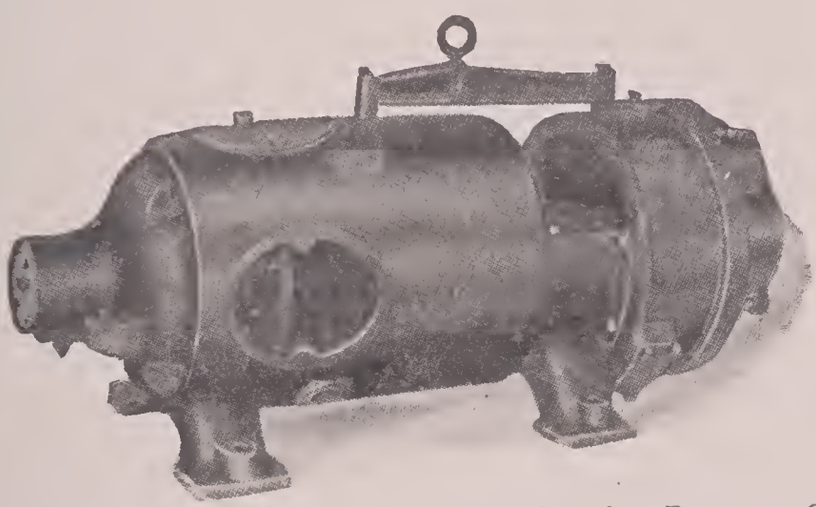


Fig. 256. 15 K. W. Turbine-Generator for Baggage Car.

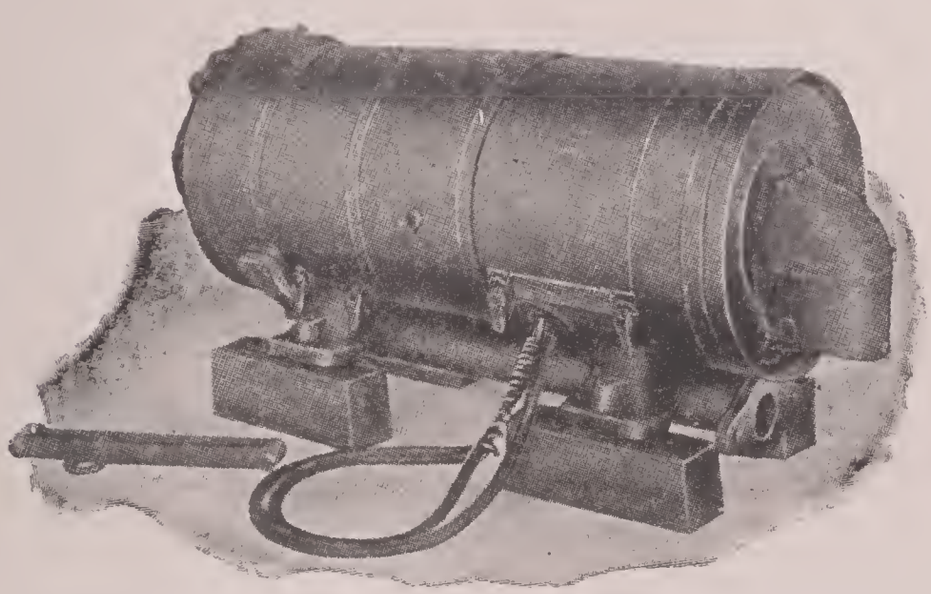


Fig. 257. 15 K. W. set with Weatherproof Casing.

When transformers and sub-stations are used the generators may deliver a much higher voltage, for the transformers step it down later, and the absence of any electrical connection between primary and secondary pro-

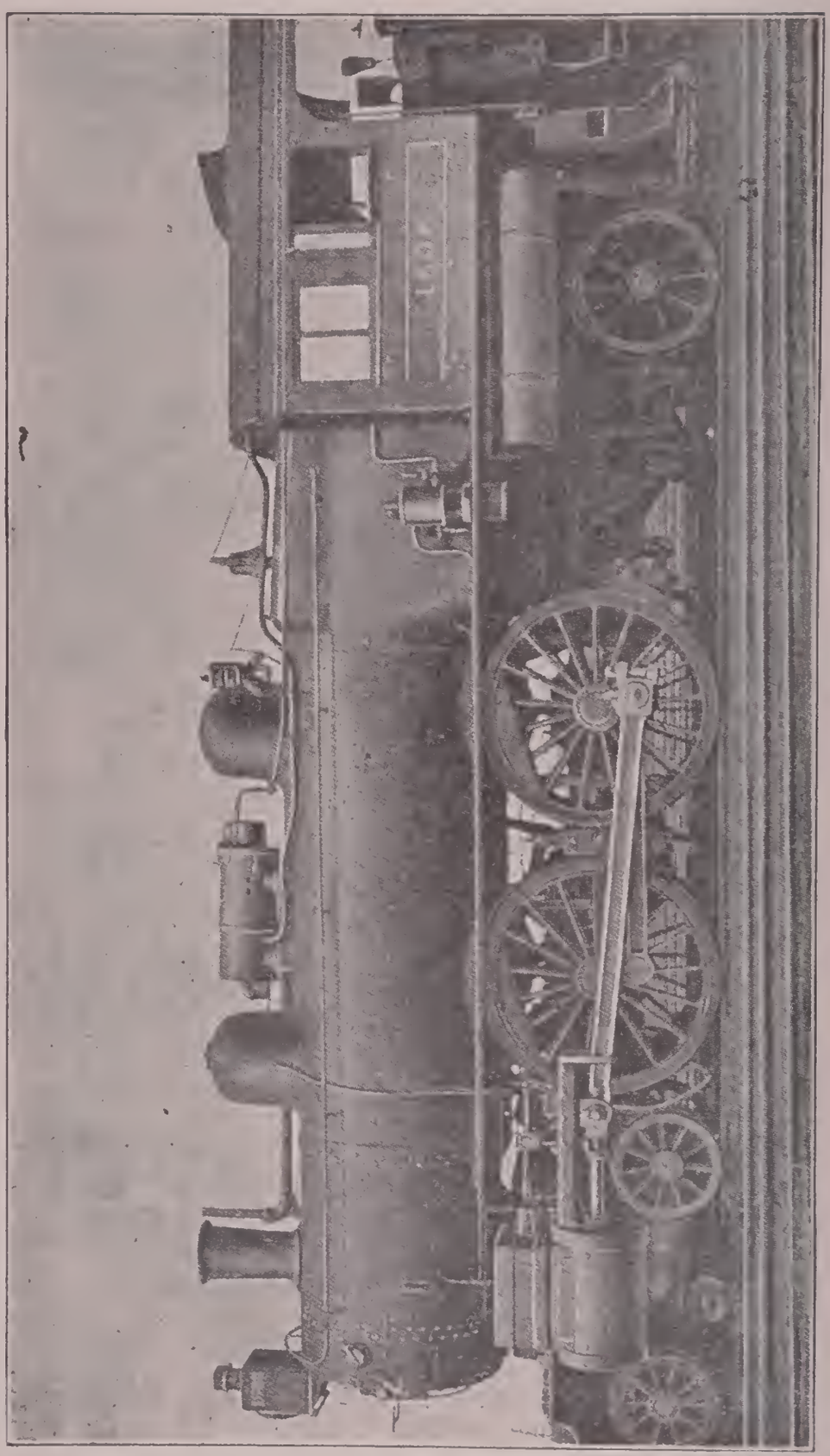


Fig. 258. Turbine-Generator on Locomotive.

tects the generator by absolutely separating it and the trolley wire.

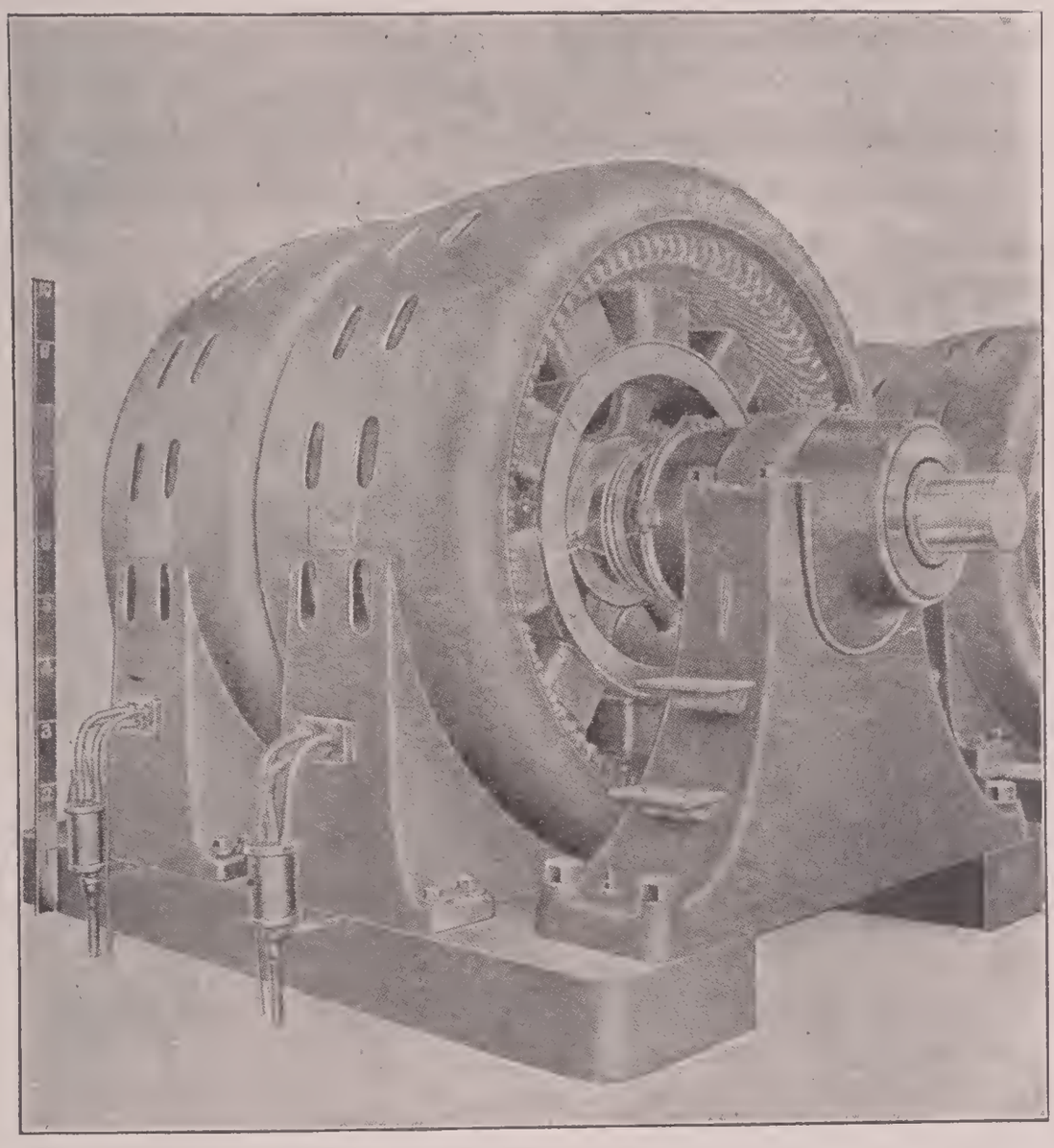


Fig. 259. A Frequency Changer.

One must remember that in A. C. work each car or locomotive carries a small sub-station, *i. e.* a transformer to lower the line voltage to a pressure suitable for the motors.

The A. C. Sub-Station.

One of the great advantages of A. C. traction is the simplicity of its sub-stations. They are small brick buildings containing the transformers for lowering voltage, a simple in-coming and out-going switchboard.

The best frequency for motors is a low one, 25 being now standard. It has been recently proposed to design systems at a frequency of 15.

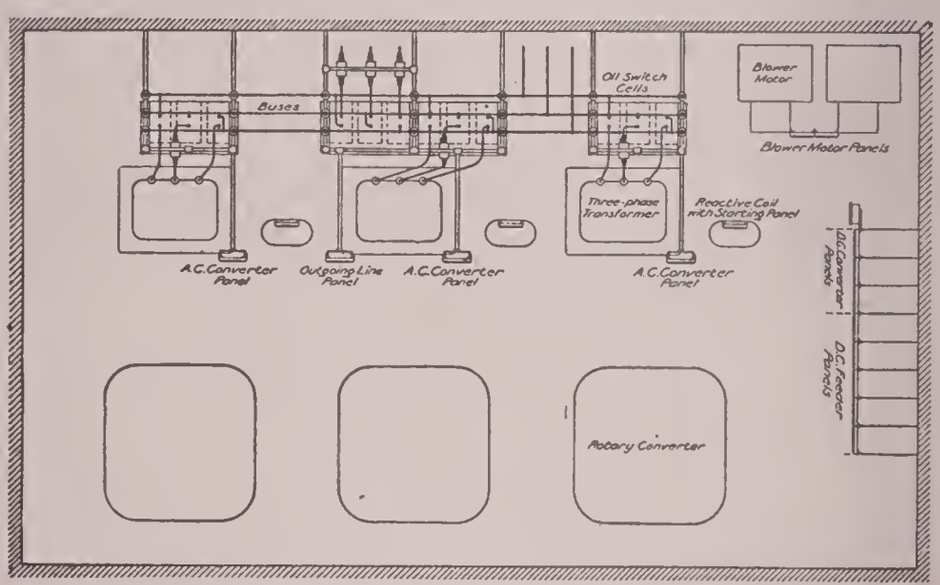


Fig. 260. Floor plan of a Typical Sub-Station.

Both of these frequencies are rather low for lighting and transformers are cheaper to build and operate as the frequency increases.

Railroads by purchase often acquire electric roads which as a side issue furnish light to some municipality. They may continue to do this at the desired frequency from their low frequency plant by installing a frequency charger, Fig. 259.

This consists of two similar machines, one a simple A. C. motor (called a synchronous motor) and the other an A. C. generator built much like an induction motor. It takes in current of one frequency and delivers current at another frequency, higher or lower as desired.

The amount the frequency is changed is determined by the design of the machine and is fixed once for all. There can be no regulation of the frequency, nor in fact is that desired; all that is needed is a change from 25 to say 133 and have it keep at 133.

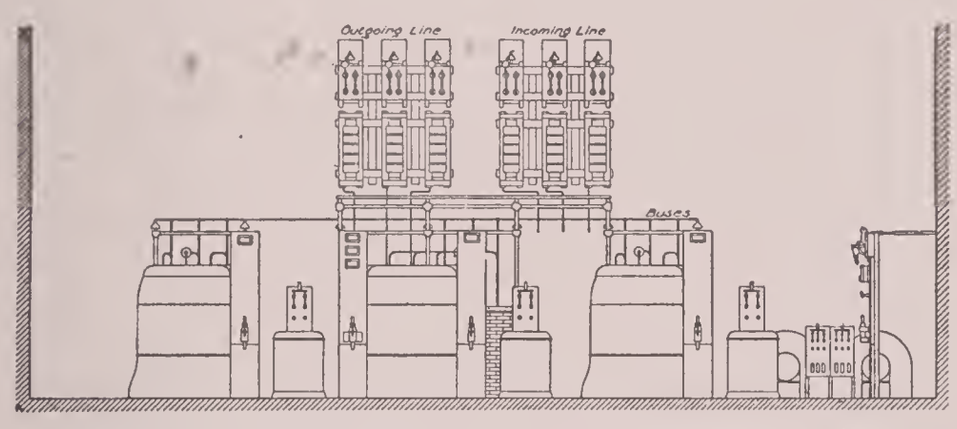


Fig. 261. View of Rear of Station Shown in Fig. 260.

The A. C to D. C Sub-Station.

When D. C. third rail or trolley is used the sub-station contains the step-down transformers which feed the rotary converters, the converters themselves, and the incoming A. C. and out-going D. C. switchboards.

The layout of a typical sub-station is shown in Figs. 260, 261 and 262. The first gives a plan of the station showing position of each piece of apparatus on the floor. The second gives view of the transformers with an A. C. panel for each rotary along side of transformer

on right. On left of middle transformer is the panel for outgoing A. C., which goes to next sub-station.

The starting resistances and switch for the rotaries are between the transformers and between the last transformer and blower panels.

High up on the wall are the two lightning arresters and fuses for the incoming and outgoing A. C. lines.

Figure 262 shows an endwise view of the station which explains itself.

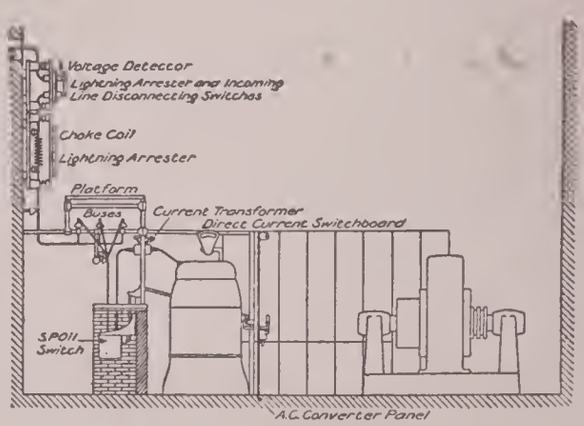


Fig. 262. End View of Fig. 260.

The sub-station shown in Fig. 263 has one complete unit in full view. It consists of a 1000 K. W., 6 phase rotary fed by a set of 3 single phase transformers connected so as to make one 3 phase transformer. These are air blast type.

At the extreme left is an induction regulator operated by a small motor on its top. This motor is controlled from the switchboard. The rotaries in this station are started from the D. C. side, for at least one rotary is always running.

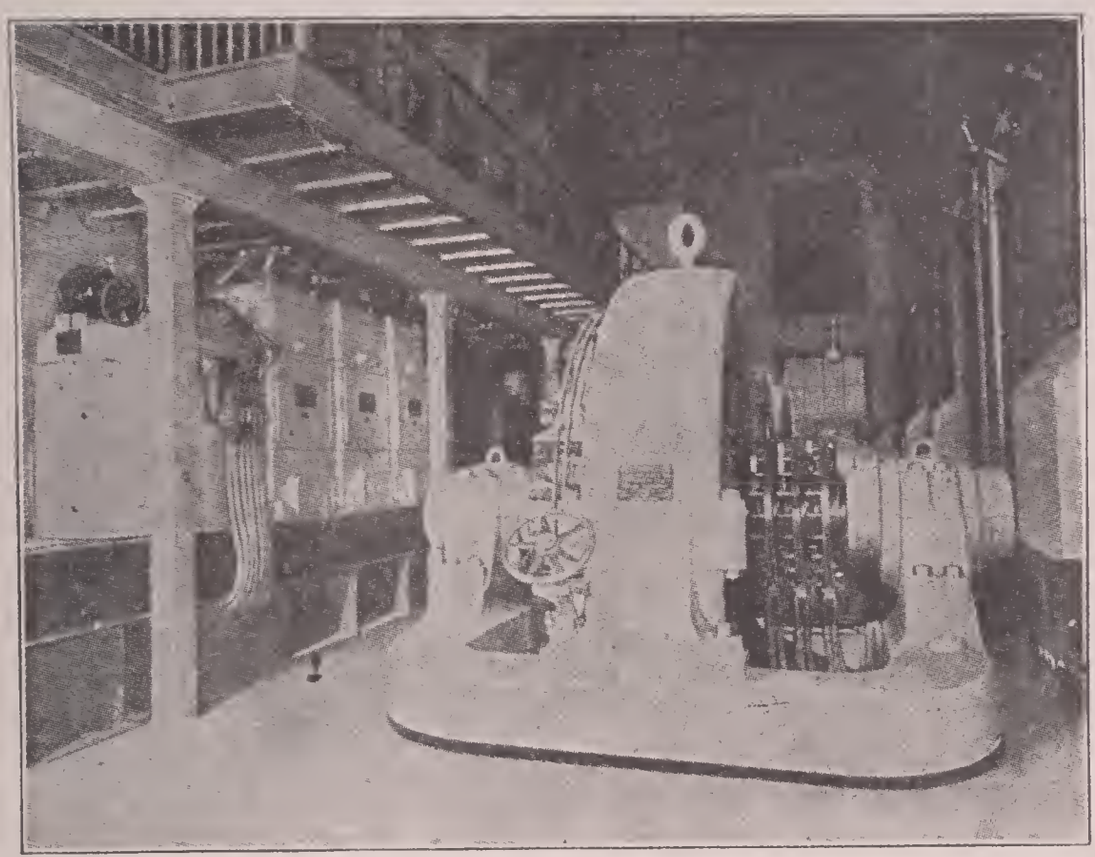


Fig. 263. Sub-Station of 6 Phase Rotaries. Surface Roads, New York.

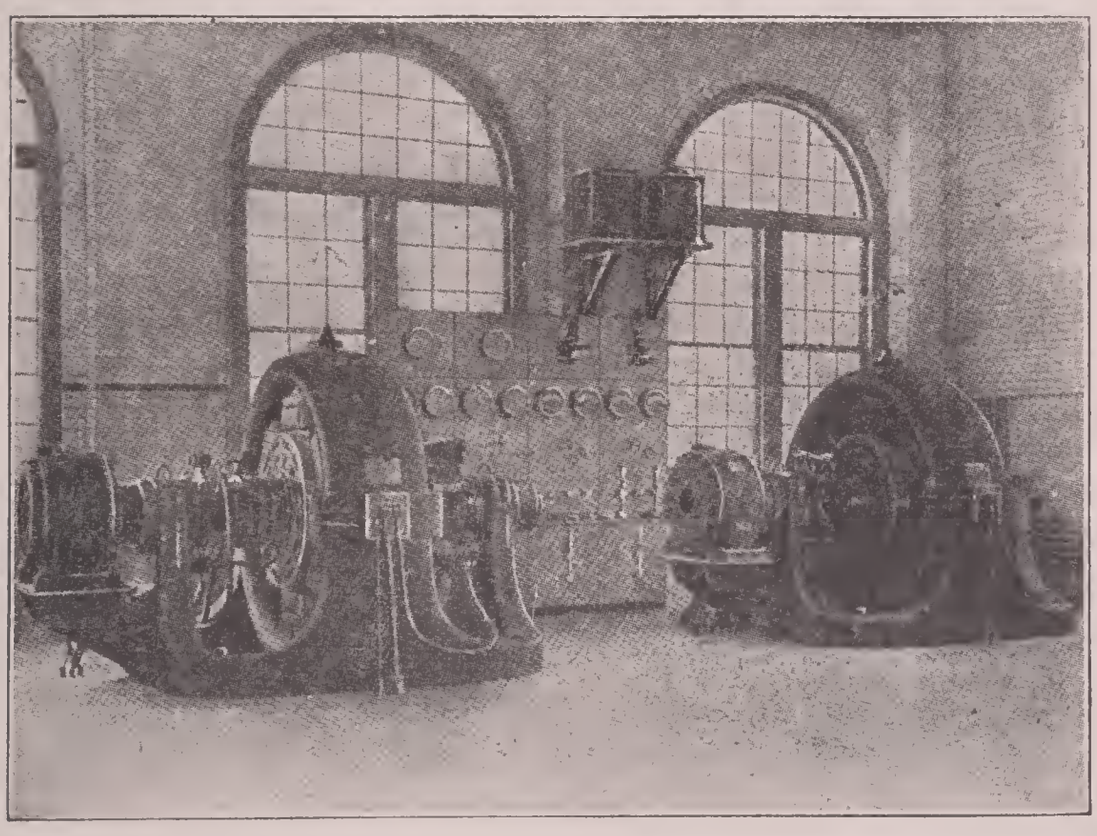


Fig. 264. Sub-Station, Rotaries with Starting Motors, Pittsfield, Mass.

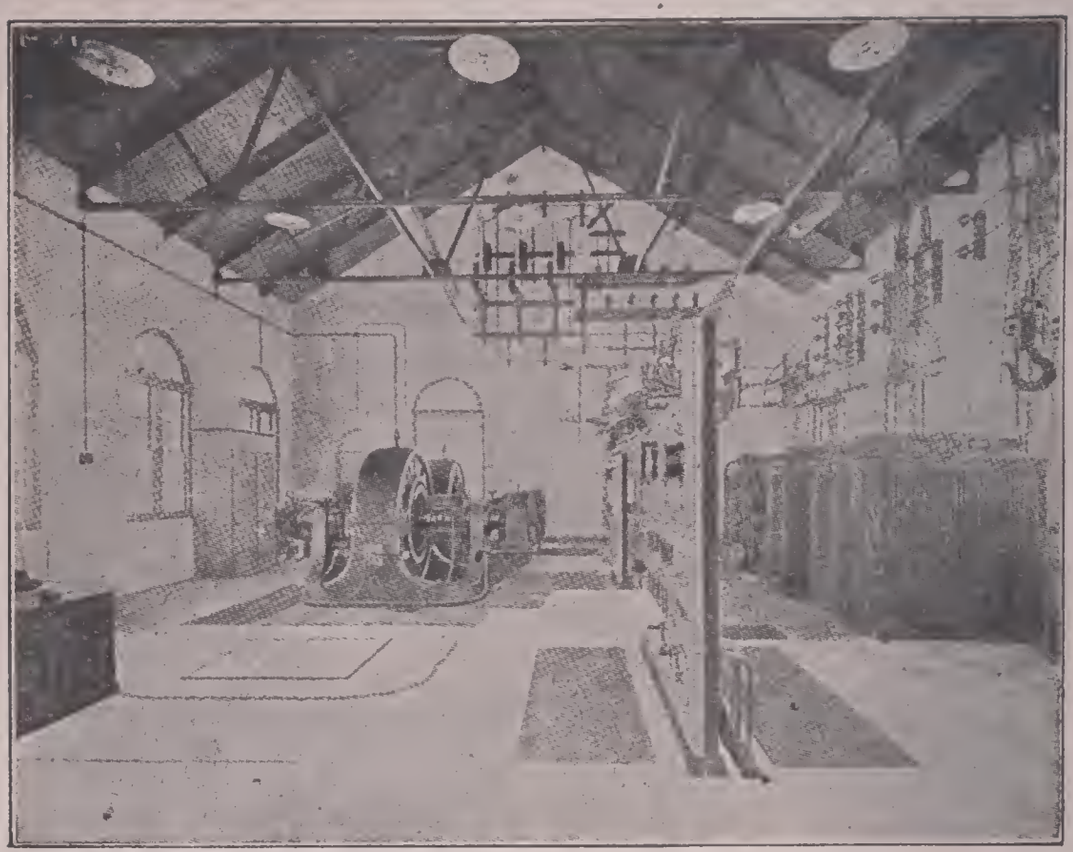


Fig. 265. Sub-Station, Utica, N. Y. Street R. R. Syndicate.

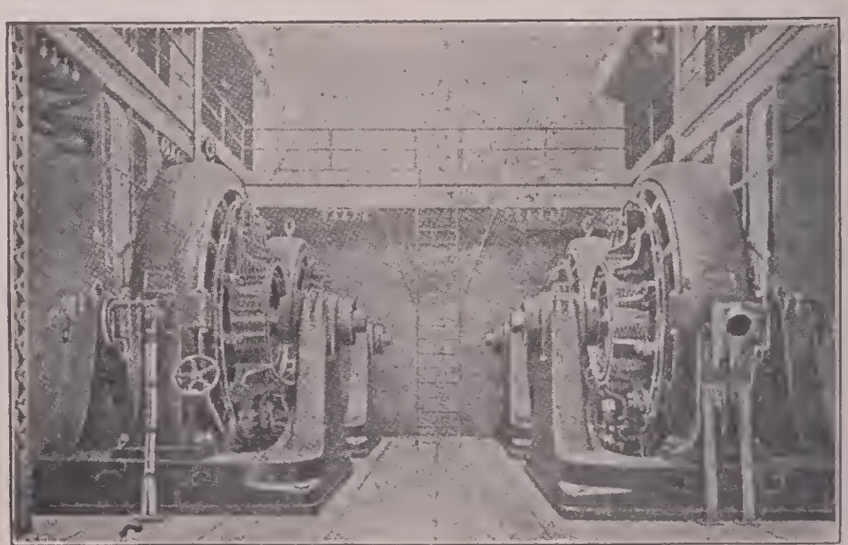


Fig. 266. Interborough Sub-Station No. 8. Four 1,500 K. W. Rotaries.

The station of Fig. 264 is a smaller installation of two 300 K. W., 3 phase rotaries. These are started by auxiliary motors, for the plant is shut down from 2 a. m. to 4 a. m. daily.

Figure 265 shows two 300 K. W. rotaries with a reserve space for another unit. These rotaries have starting motors. The switchboard runs down center of room and behind it are the transformers.

Figure 266 shows four 1500 K. W. rotaries in Substation No. 8 of the Interborough Railroad.

Figure 267 shows a rotary converter with switchboard. At extreme rear are the transformers.

Synchronous Motor.

If two similar single phase machines are connected to a line the one may be driven as a generator and the other considered as a motor. This motor will not start when its switches are closed, because the rapid changes of the armature polarity give impulses to move first in one direction and then in another; with the result that motor stands still.

If the motor machine should be revolved by a smaller motor till it is moving at the same speed as generator, or slightly faster, when the switches of the motor are thrown the motor will continue to revolve at generator speed.

Such a motor will carry any load up to 50% overload without the slightest change in speed until suddenly it stops. To get it started again the load must be thrown off and the motor brought up to its proper speed by the auxiliary motor.

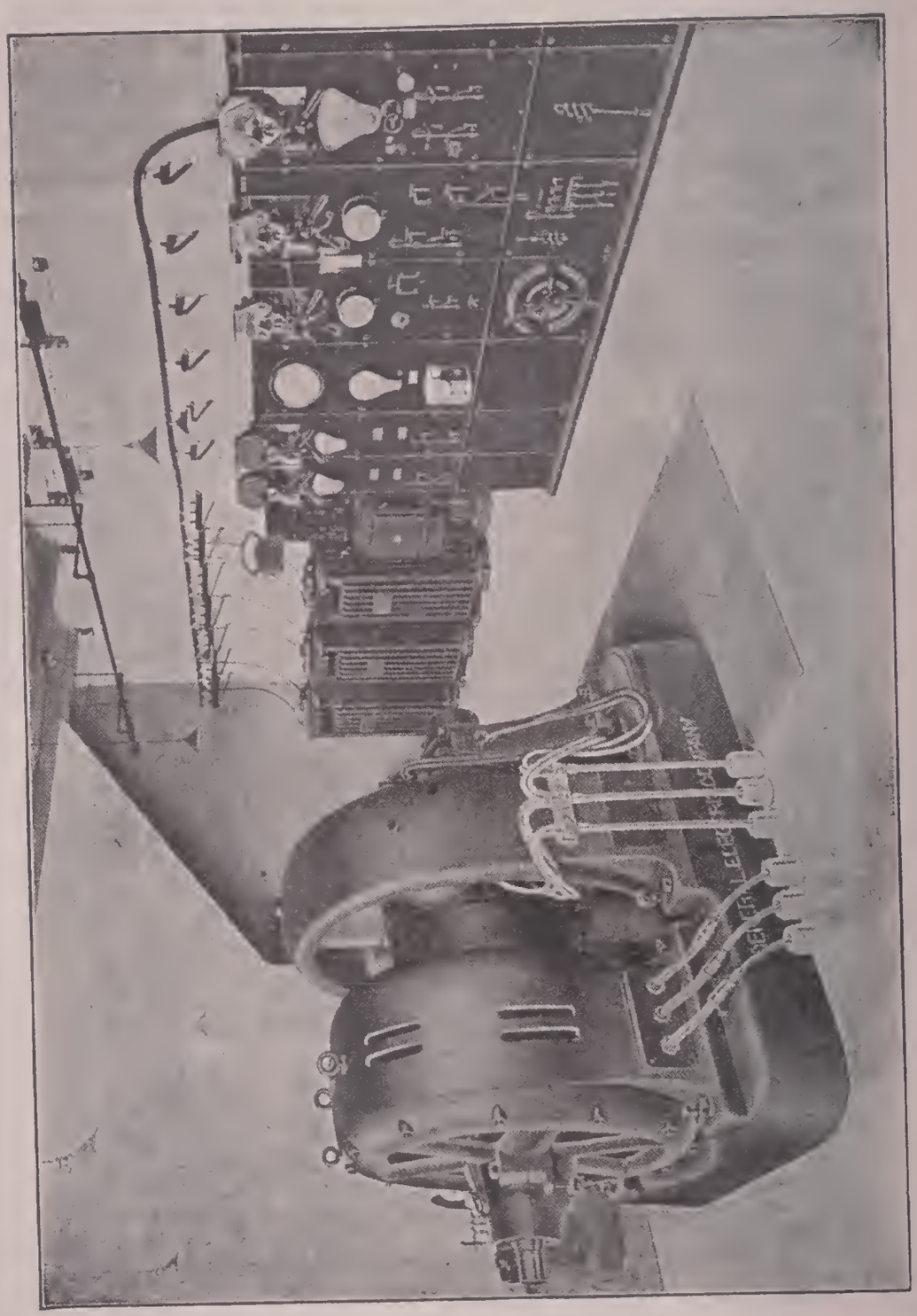


Fig. 267. Sub-Station.

The D. C. for the motor field is supplied to the motor from external source. The strength of the field has no influence on the speed of motor.

The speed is governed by the frequency of generator. If the generator passes 25 pairs of poles a second then the motor will also do so. If the generator and motor have the same number of poles then they revolve the same number of revolutions per minute. A 32 pole generator driving a 16 pole motor goes only half as fast as the motor, for if frequency of generator is 25 the motor must go twice as fast so as to pass the same number of pairs of poles a second.

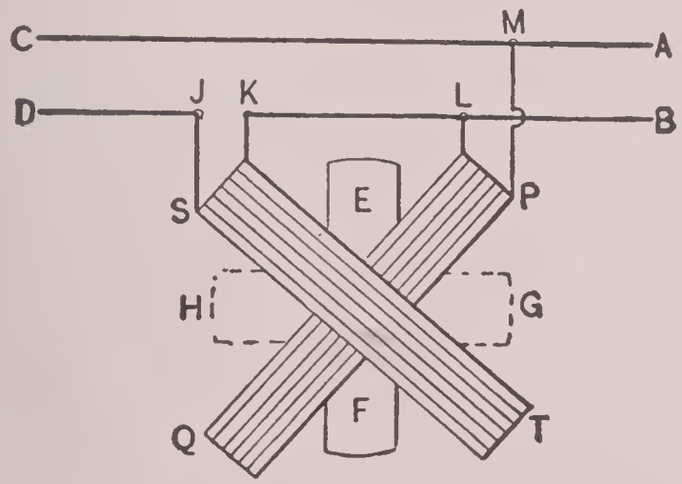


Fig. 268. Induction Regulator.

Induction Regulation.

If the current going to a rotary passed through an auto transformer where part of the coil could be placed in opposition to the rest of it, then we would have an arrangement capable of slightly lowering or raising the voltage applied to rotary, according as the part of coil was in series or in opposition to the rest of the coil.

The *induction regulator* produces the same effect in a little different way. It is as shown in Fig. 268. It con-

sists of a primary P. Q. of a transformer across the line as a shunt and a secondary S. T. in series with one of the mains.

An iron core E. F. when in this position causes the flux to pass through secondary and induce an E. M. F., which is added to the line, while if turned by the handle or by motor into position H. G. the flux through S. T. is reversed and the E. M. F. induced is subtracted from the line. This transformer carries full current, but induces so few volts that the power is small. When only 3 or 4% of its own power is lost, it is a very small fraction of total power delivered to rotaries.

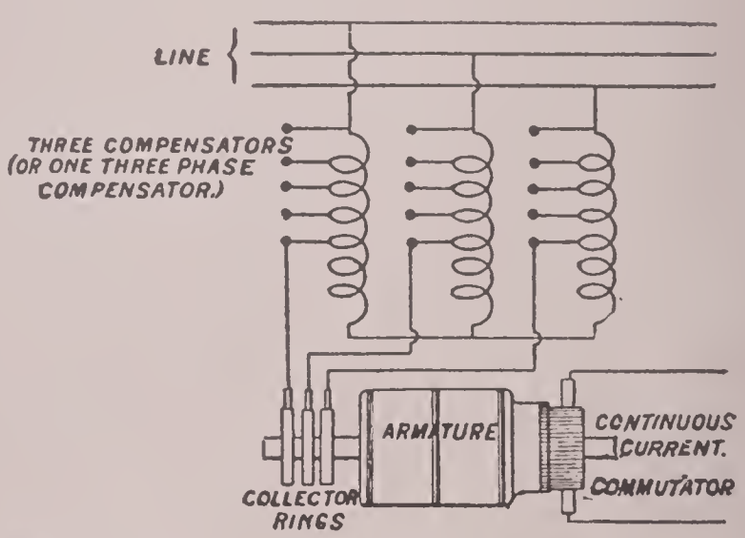


Fig. 269. Starting 3 Phase Rotary with Compensator.

Starting Rotary Converters.

To start from the A. C. mains as a polyphase motor the connections shown in Fig. 269 are used.

The line in this case has a compensator attached and as shown in Fig. 269 the rotary will now receive only a fraction of the line voltage, and starts at slow speed.

As the taps to rotary are moved up the coils the voltage is higher until finally the coils of compensator are cut out entirely and rotary is revolving at full speed, taking full line voltage.

When transformers are between line and rotary the same scheme is applied to the secondaries of the transformer.

To start from D. C. mains a regular starting set is used and operation is like any shunt motor.

Synchronising.

When a rotary is up to speed and ready to be connected to the A. C. line, it must be connected at just the right instant.

This time can be determined by bridging across the connecting switch some lamps in series.

Both the rotary and the incoming line will be operating these lamps. As a result they will flicker. As the right instant is approached the lamps blink slowly until the change from darkness to light takes one or two seconds; then at the time of maximum brightness or darkness close the connecting switch. The lamps may then be disconnected.

Two voltmeters can be combined in one case and made to indicate through a single pointer. When the line and rotary agree the pointer stands in center of dial. These are called synchronism indications or synchronizers.

By synchronism for two alternators we mean that the maximum value of the E. M. F. in each machine occurs at exactly the same instant. They are then in phase, and

in step and in synchronism. In this condition they run as generators in parallel.

If they get out of phase sufficiently they will keep in step and in synchronism but will be in opposition and one will continue to generate while the other will begin to absorb power and act as a motor. This is what is meant by synchronism for an alternator and a rotary converter.

LESSON 31.

SWITCHBOARDS.

A knowledge of switchboards and their wiring is of great value to a power house attendant and of great interest to all the men in operating department.

Switchboards are made up of panels of slate on a frame of angle iron. Each panel is designed for certain work so that a description of the different kinds of panels is sufficient.

The first board to consider is the D. C. outgoing line board, served from D. C. generators.

D. C. Generator Panels.

Fig. 270 shows three generator panels each of which is regularly equipped from a capacity of 250 to 6500 amperes with

1 Carbon break or magnetic blow-out circuit breaker, with telltale.

1 Illuminated dial ammeter with shunt.

1 Hand wheel and chain for operating rheostat.

1 Receptacle for voltmeter plug.

1 S. P.-S. T. field switch.*

1 S. P.-S. T. main switch.

1 Recording Watt-hour meter.

*S. T. means single throw.

D. T. means double throw, i. e. the switch has two sets of clips and can be thrown into either of them.

S. P. means single pole.

D. P. means double pole, i. e. opens both sides of circuit.

T. P. means triple pole, i. e. opens every conductor of a 3 phase system.

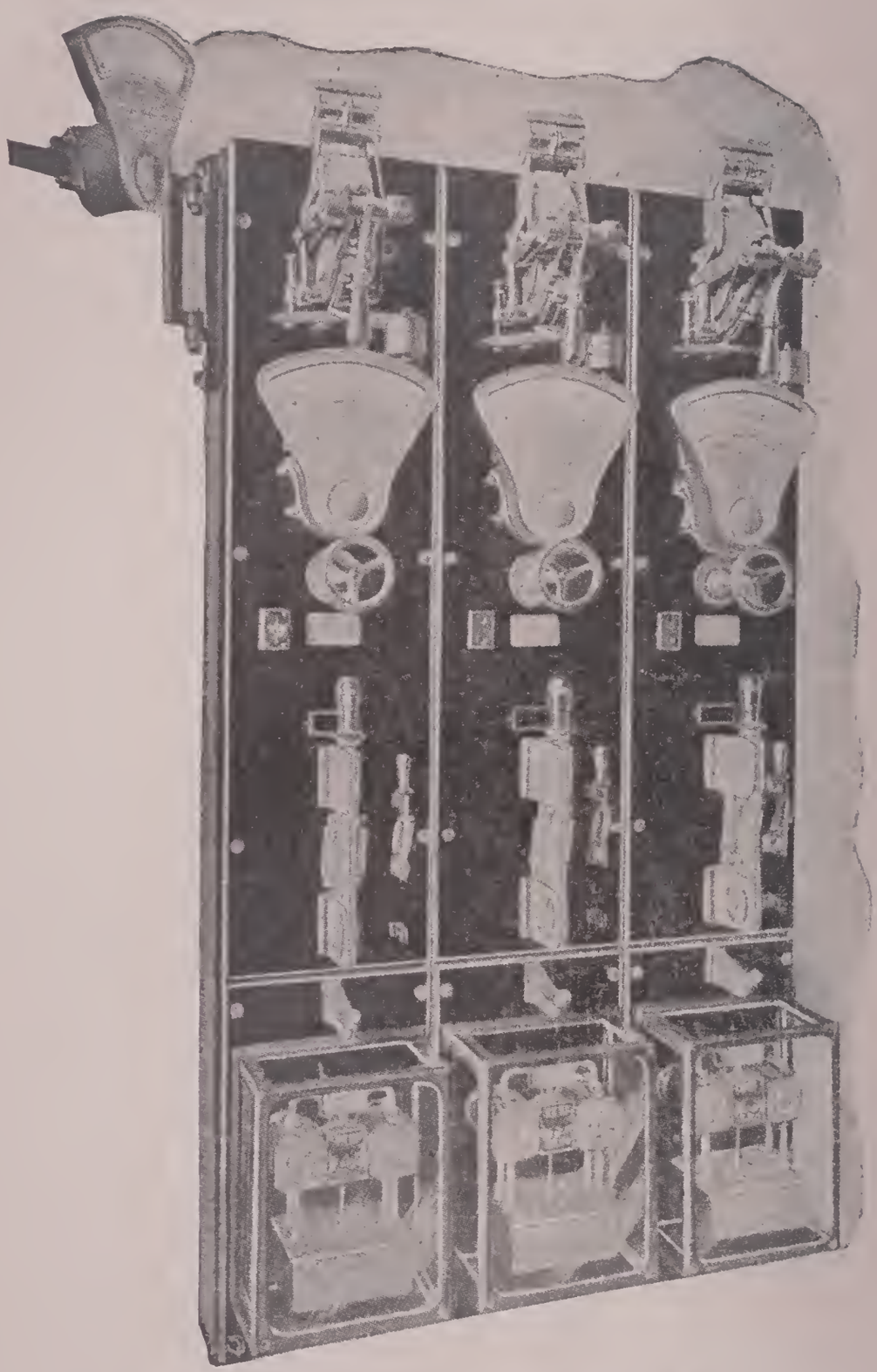


Fig. 270. D. C. Generator Panels.

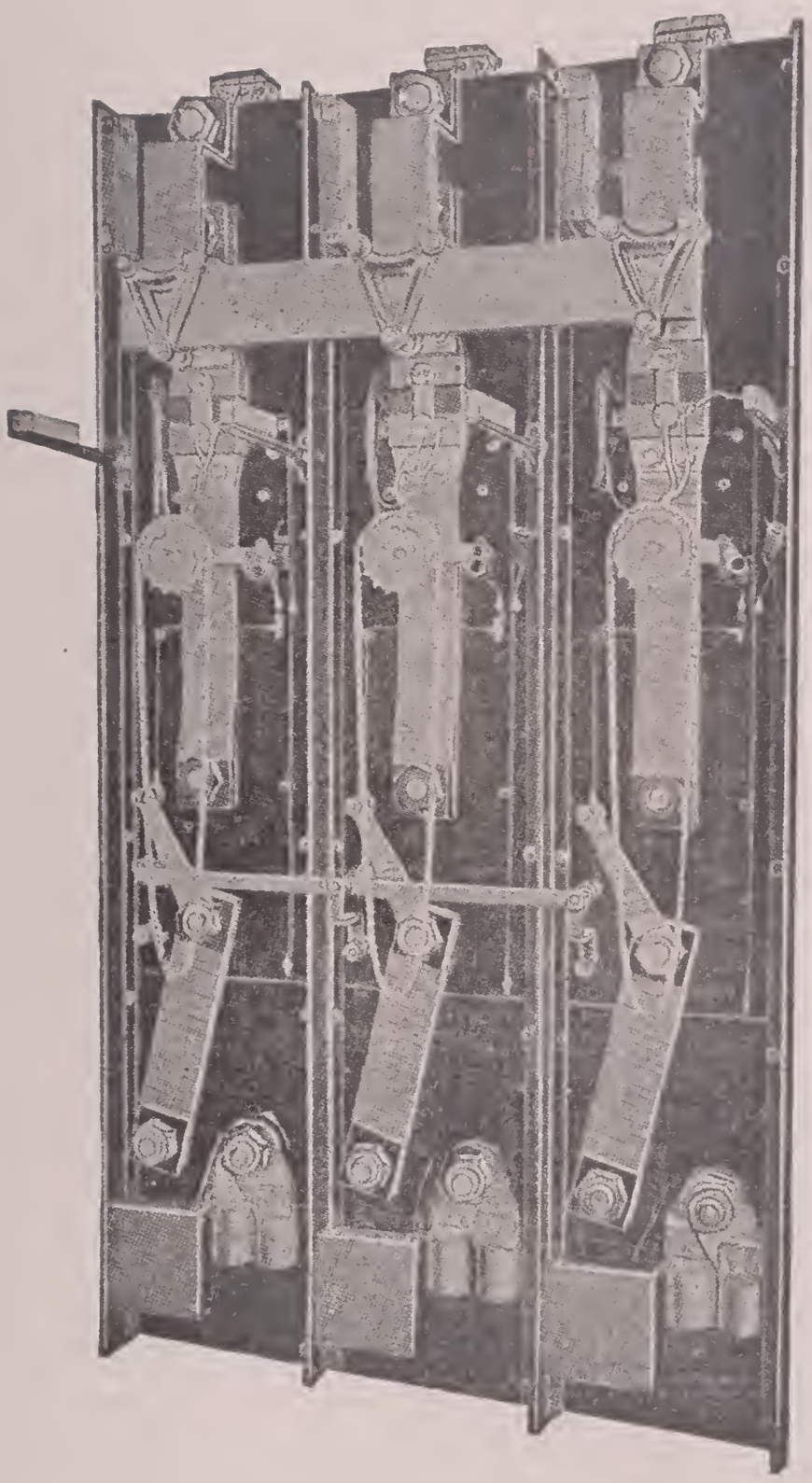


Fig. 271. Rear View of Fig. 270.

A rear view of these panels is shown in Fig. 271.

The best practice puts a main switch at the machine so that the cables from machines to board may be cut off from generator. It is also good practice to run the equalizer cable along in ducts from machine to machine without carrying it to the board.

This equalizer connects the junctions of series field and brush on all machines as shown in Fig. 272; the shunt coils being omitted to simplify diagram.

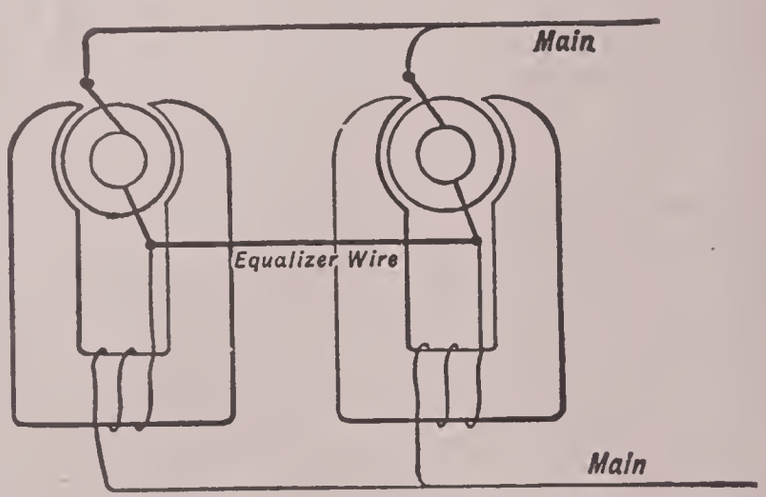


Fig. 272. Equalizer.

It is best to place the main switch and equalizer switch on a pedestal panel as shown in Fig. 273 for moderate capacity and in Fig. 274 for 4000 ampere (and larger) machines. The upper switch being the main switch. The rear view of these large capacity pedestals is shown in Fig. 275.

A better view of the 4000 ampere toggle operated main switch is given in Fig. 276. The quick-break S. P.-S. T. switch is illustrated in Fig. 277.

The field switch, Fig. 278, has a carbon break. Just before the switch opens it makes contact with an extra clip which puts a resistance on as a shunt around the field coils.

Fig. 273. Pedestal Panel for Main and Equalizer Switches. Small Capacity.

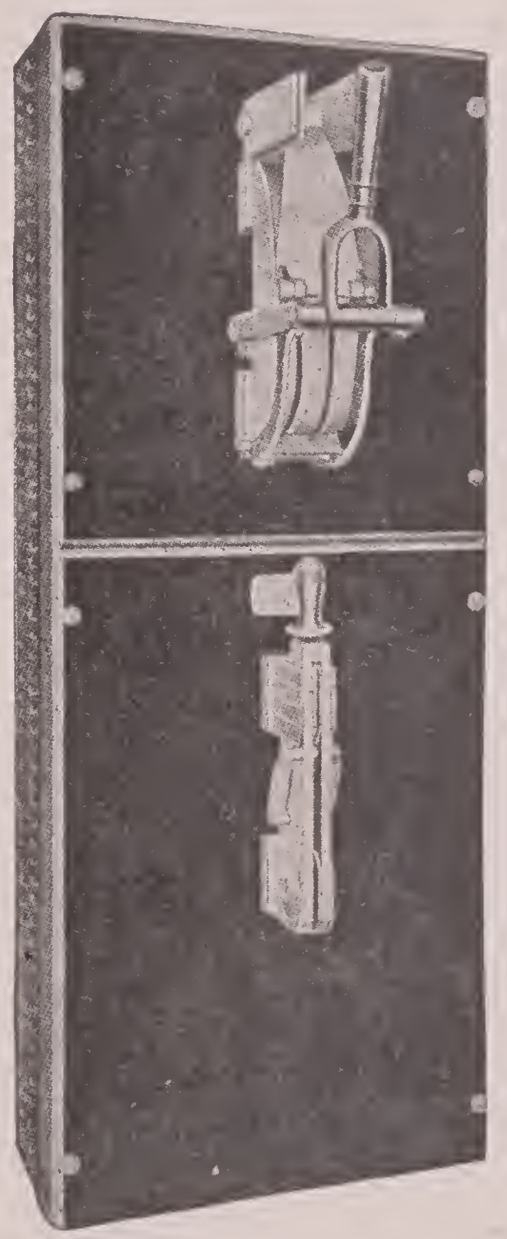


Fig. 274. Main and Equalizer Switches for Large Capacity.

If this were not done the fields would act like a kicking or spark coil and their insulation be damaged.

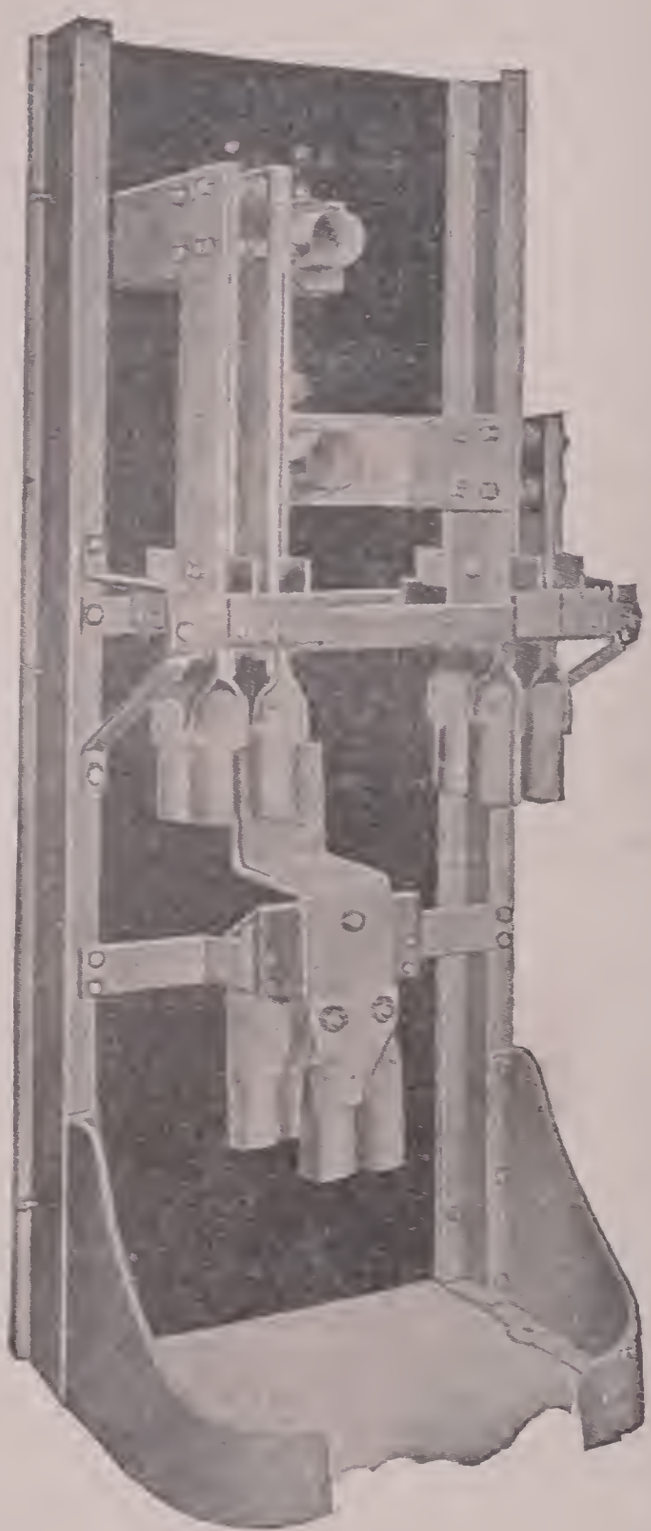


Fig. 275. Rear View of Fig. 274.

In Fig. 279 is seen the diagram of the panel shown in Figs. 270 and 271 when capacity is 800 K. W. or under.

Fig. 280 shows the same panel when capacity is larger. The panel at left is for 1000 and 1200 K. W., the next

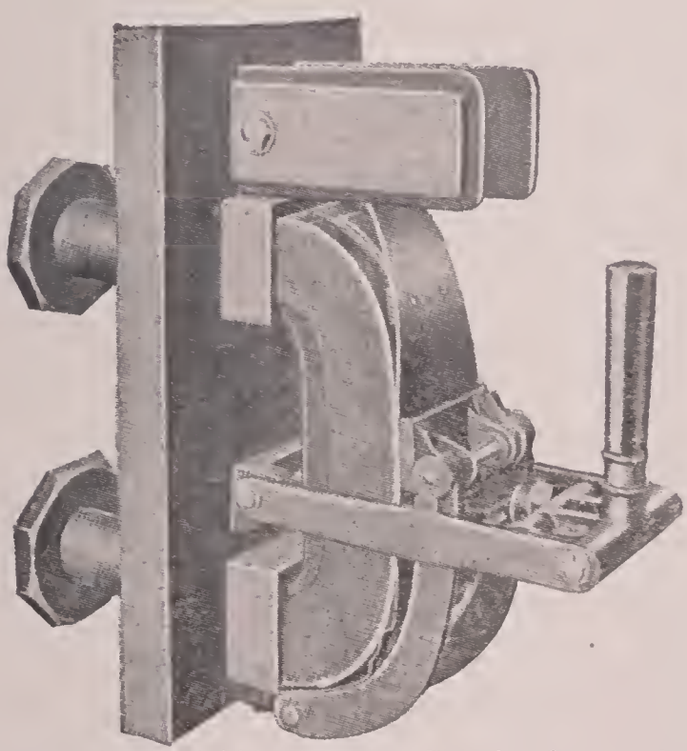


Fig. 276. 4,000 Ampere Toggle Operated Switch. Laminated Main Contact, Carbon Secondary Contact with Magnetic Blowout.

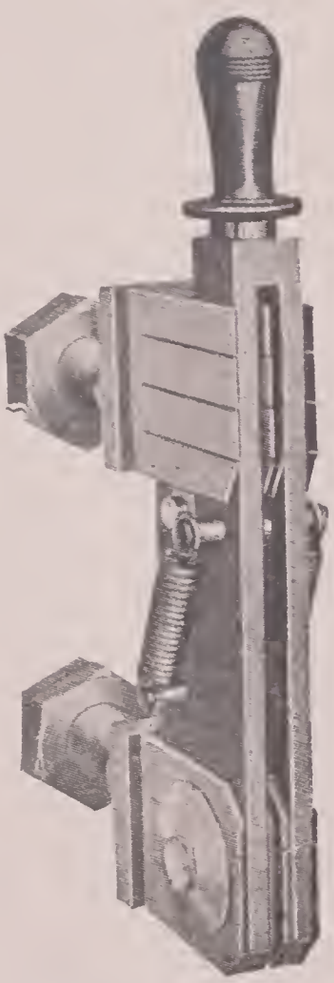


Fig. 277. 3,600 Ampere Quick Break Switch.

for 1500 K. W. and over. The cuts on right side show the back and side view of the 1500 K. W. panel.

The scheme of electrical connections for panel of Fig. 270 is shown in Fig. 281.

D. C. Feeder Panels.

A set of feeder panels for one feeder each is shown in Figs. 282 and 283, a panel for two feeders with separate switches and one ammeter reading sum of both currents is shown in Fig. 284, while Fig. 285 has an instrument and switch for each circuit.

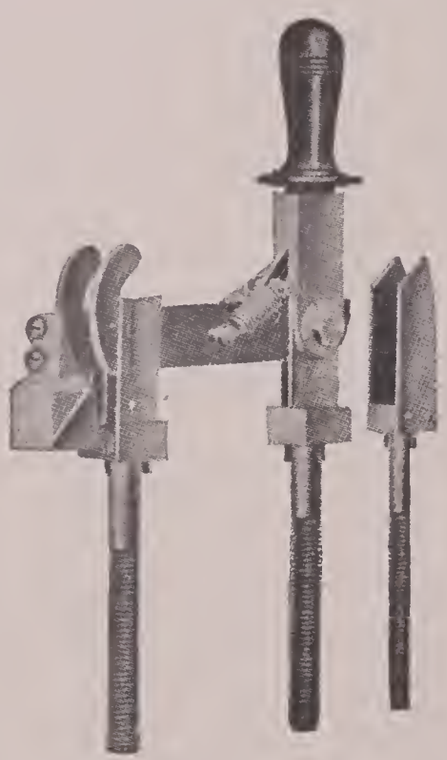


Fig. 278. Field Discharge Switch.

Fig. 286 gives the diagram of these feeder panels and Fig. 287 gives the electrical connections.

With panels as described the way to throw a generator in parallel with other generators already running, the following procedure should be followed:

First—Close main and equalizer switches (on pedestal or panel near machine).

Second—Close field switch (on panel).

Third—Close circuit breaker.

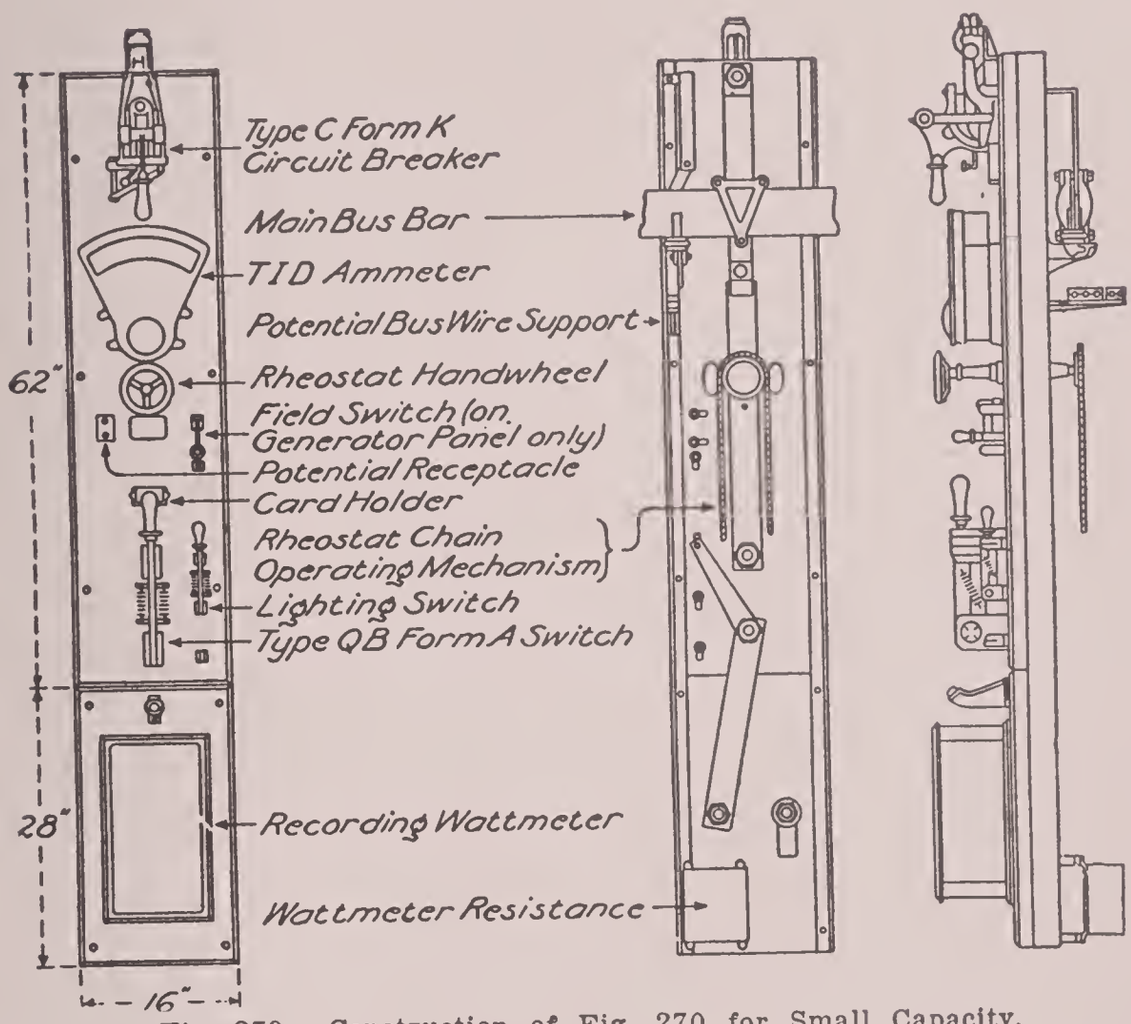


Fig. 279. Construction of Fig. 270 for Small Capacity.

Fourth—Insert potential plug in receptacle and regulate voltage.

Fifth—When the proper voltage is obtained, close the other main switch (on panel).

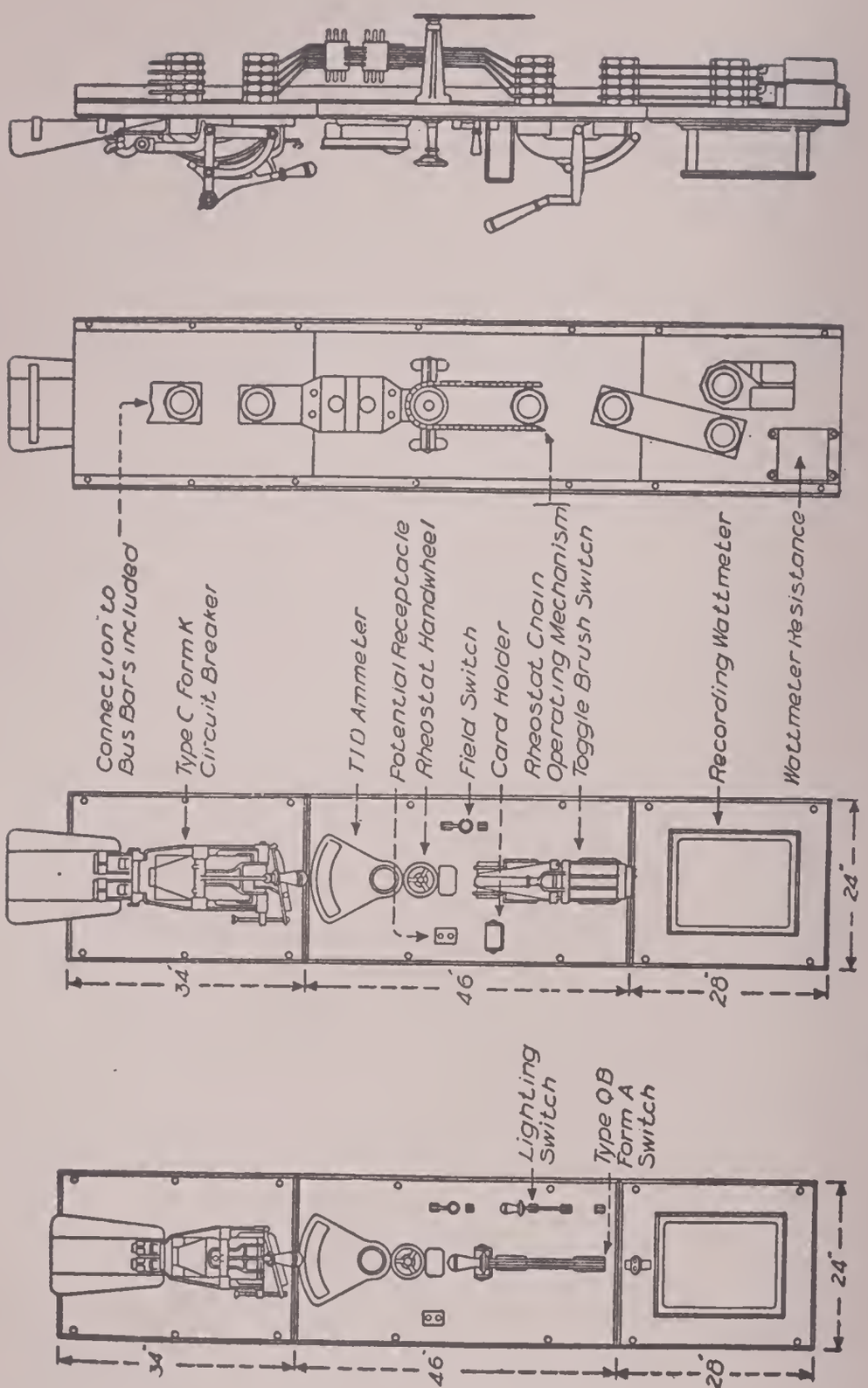


Fig. 280. Construction of Fig. 270 for Large Capacity.

All the above applies to the distributing of the out-put of rotary converters, but as they have some peculiarities they will be considered later.

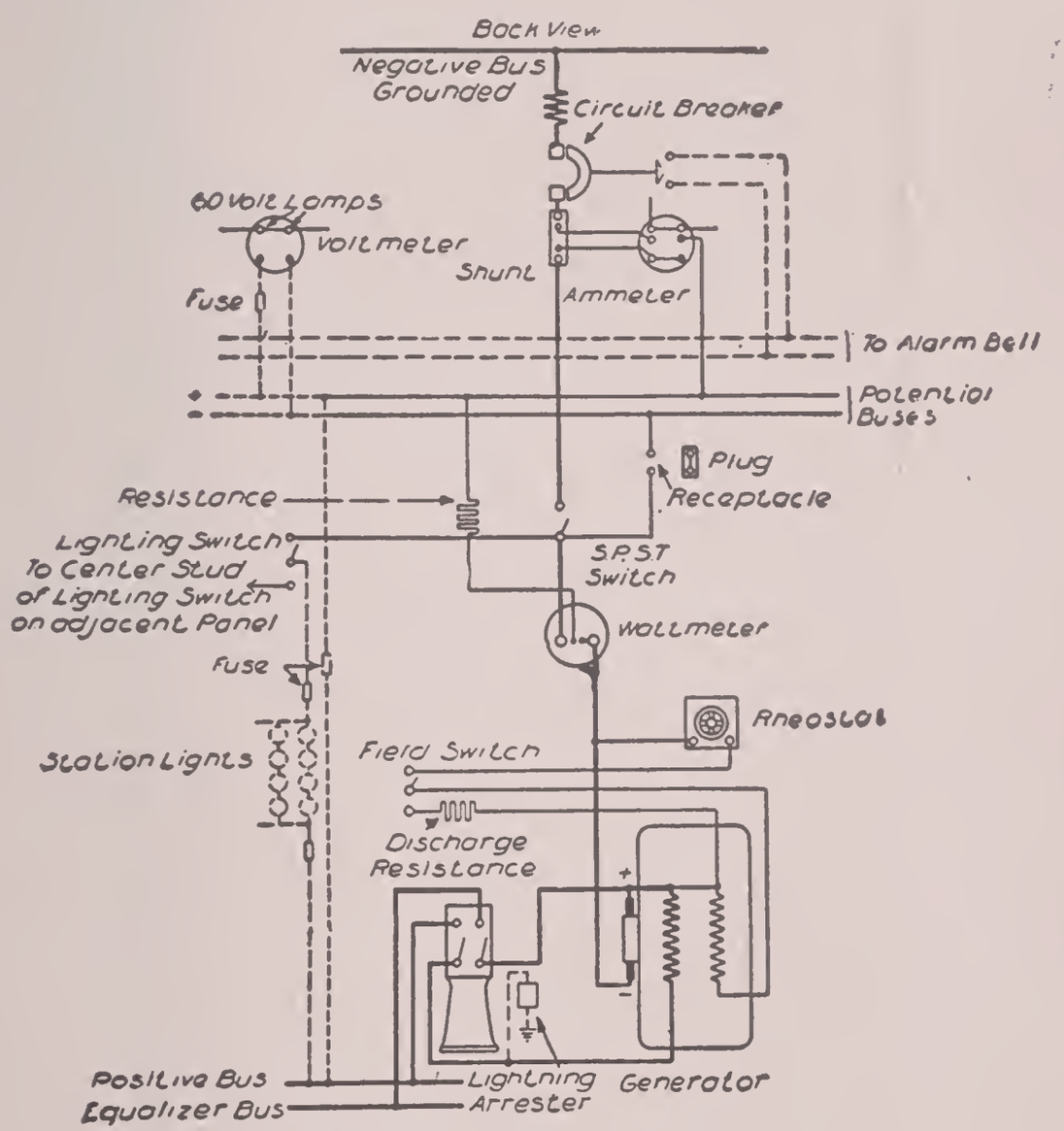


Fig. 281. D. C. Generator Panels

Nearly all railroads are operated by a 3 phase station although the trains are run by single phase A. C. or by converted power as D. C.

The consideration of 3 phase A. C. switchboards will cover all the A. C. power houses.

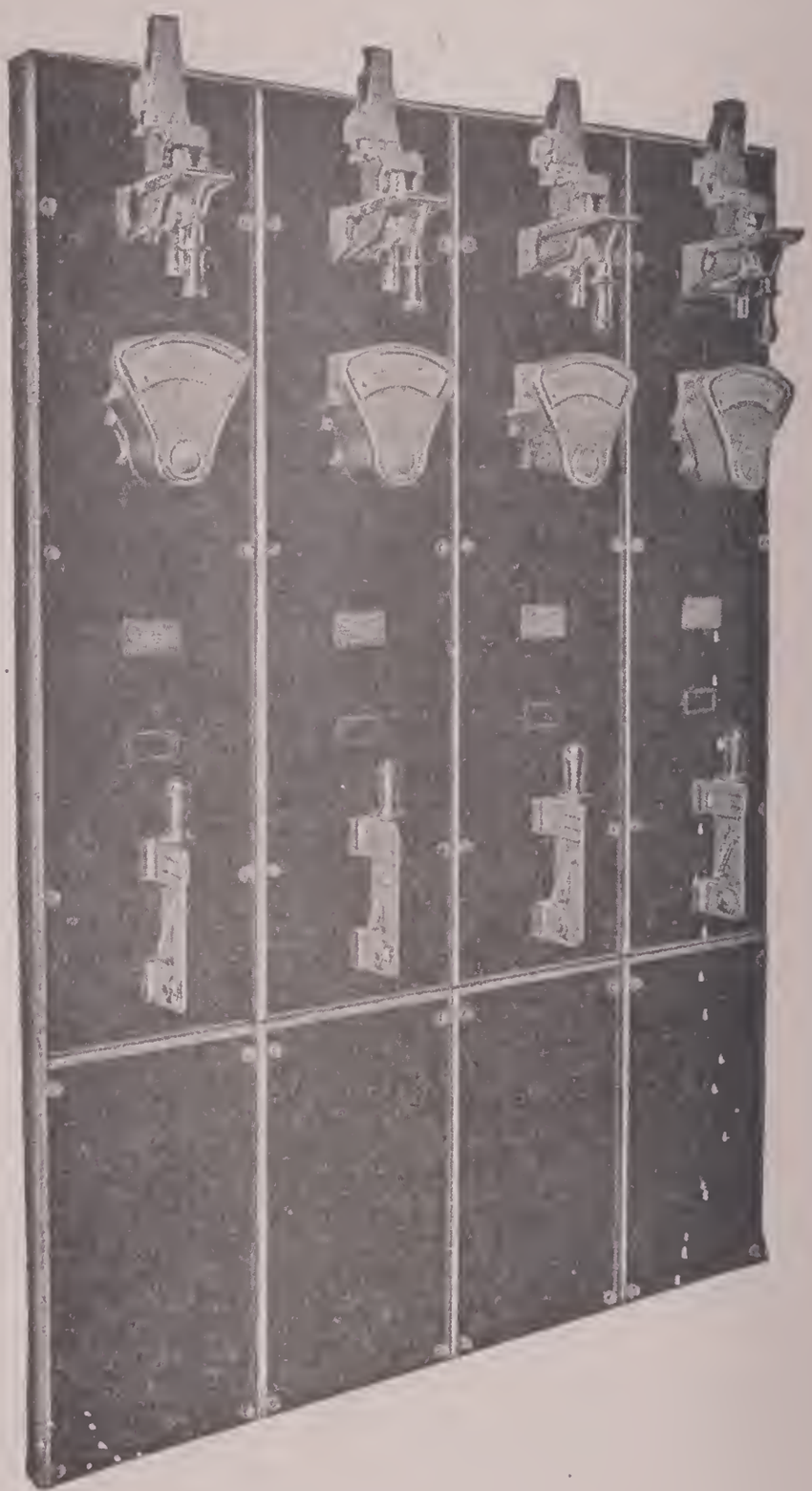


Fig. 282. D. C. Railway Feeder Panels.

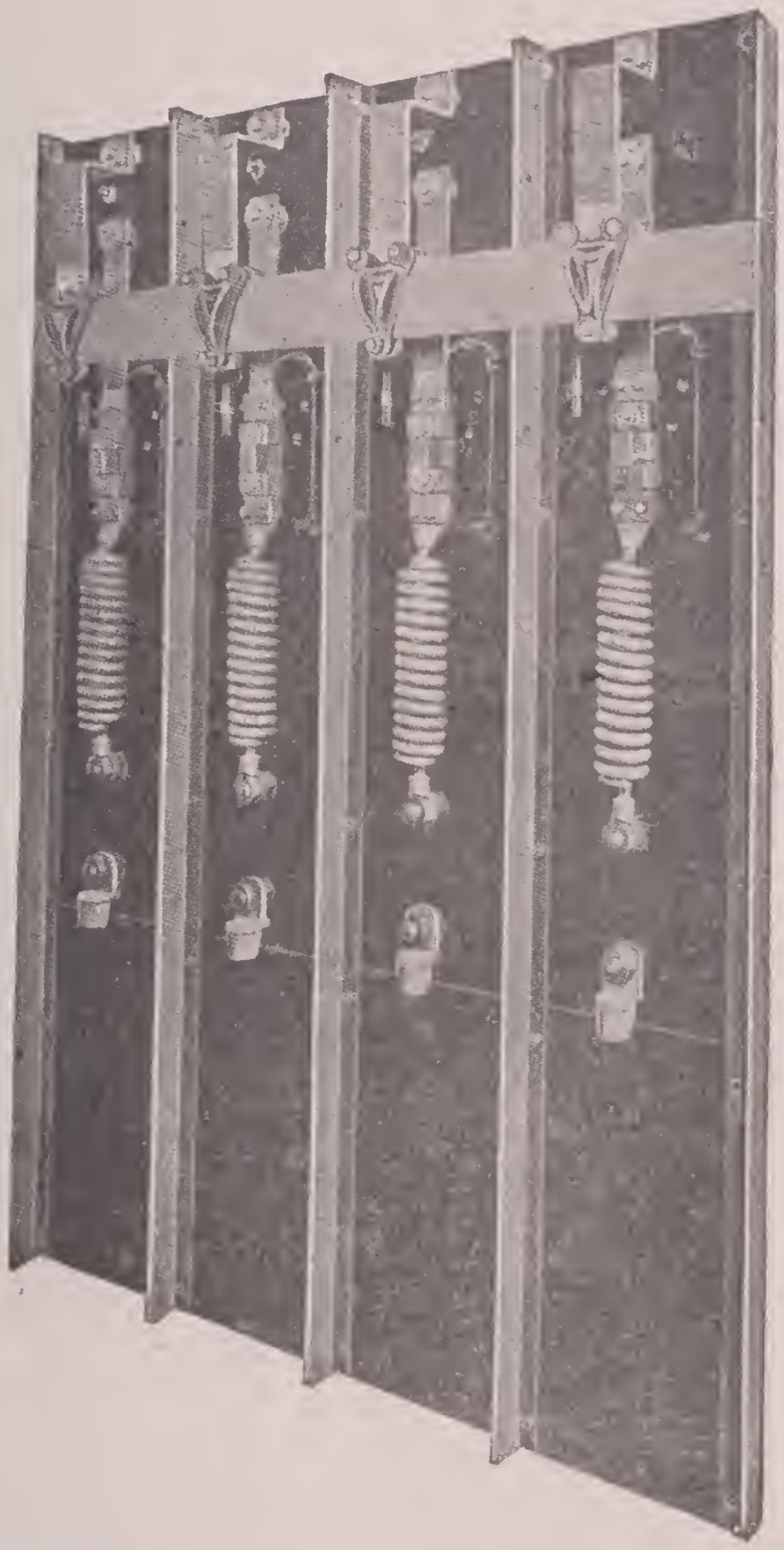


Fig. 283. Rear View of Fig. 282.

Fig. 284. Two Feeder D. C. Panel.

Fig. 285. 1,200 D. C. Ampere Railway Feeder Panel for Two Circuits.

A. C. Generator Panel.

The panel in Fig. 288 contains:

1 Horizontal edgewise balanced three-phase indicating wattmeter, arranged for reading both the kilowatts output and the wattless component.
1 Horizontal edgewise ammeter.
1 Horizontal edgewise voltmeter.
1 Balanced three-phase induction recording wattmeter.
1 D. P. D. T. potential reversing switch for the indicating wattmeter.
1 Four-point receptacle for synchronizing connections.
1 Hand-wheel and chain operating mechanism for field rheostat.
1 S. P. S. T. carbon break field switch with discharge clips.
1 D. P. D. T. engine governor control switch.
1 T. P. S. T. oil switch.
1 Current transformer for instruments.
2 Potential transformers for instruments.

The functions of the instruments are to indicate the current, voltage and kilowatts output of the generator, and the wattless component of the output. For indicating the wattless component and potential coil of the indicating wattmeter is wired to the potential reversing switch, which is normally held by a spring so as to connect the instrument up as a wattmeter. By throwing the switch against the spring into the other position the potential coil is reversed and the instrument reads the wattless component, giving a ready means of detecting

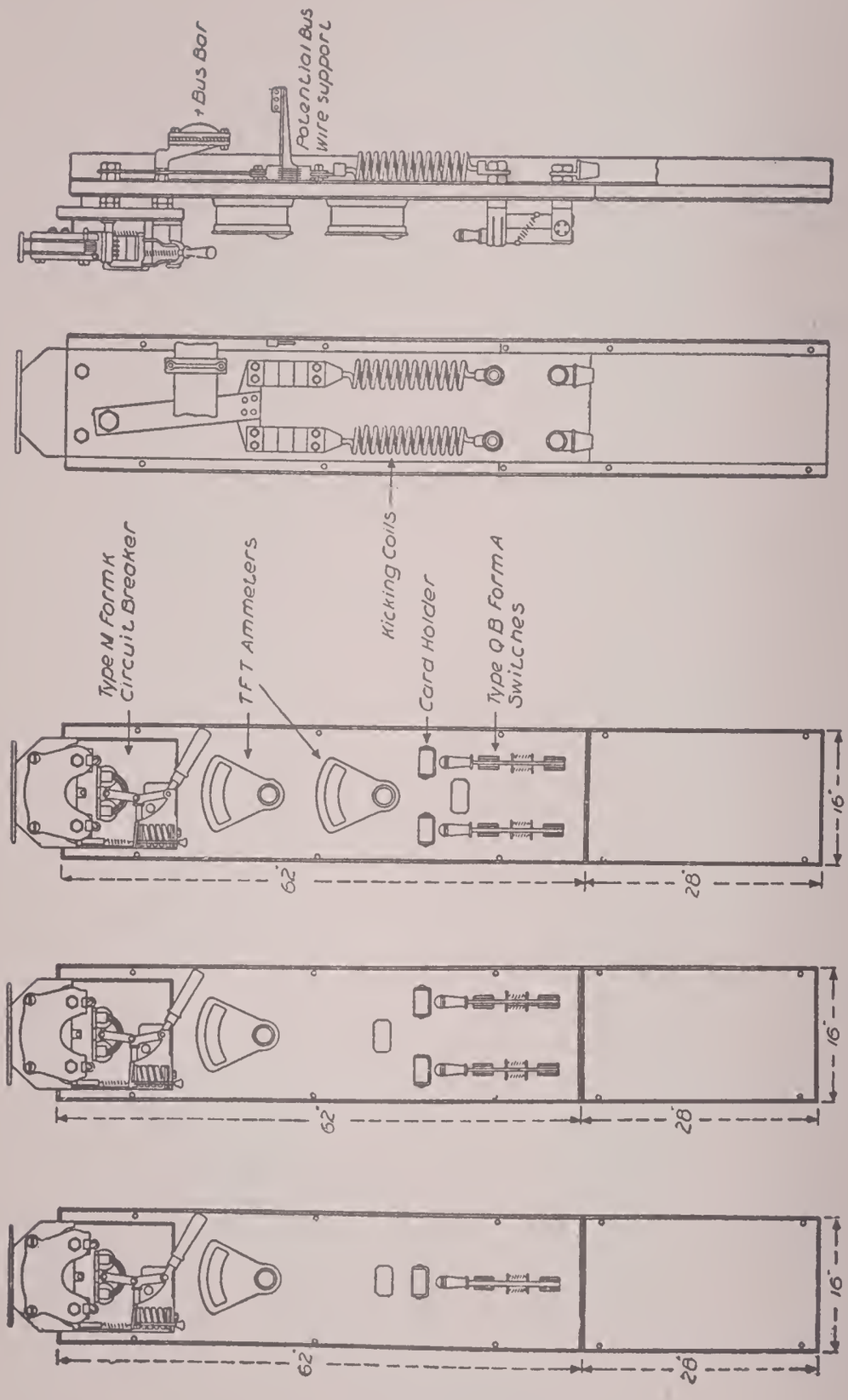


Fig. 286. Construction of Figs. 282 and 285.

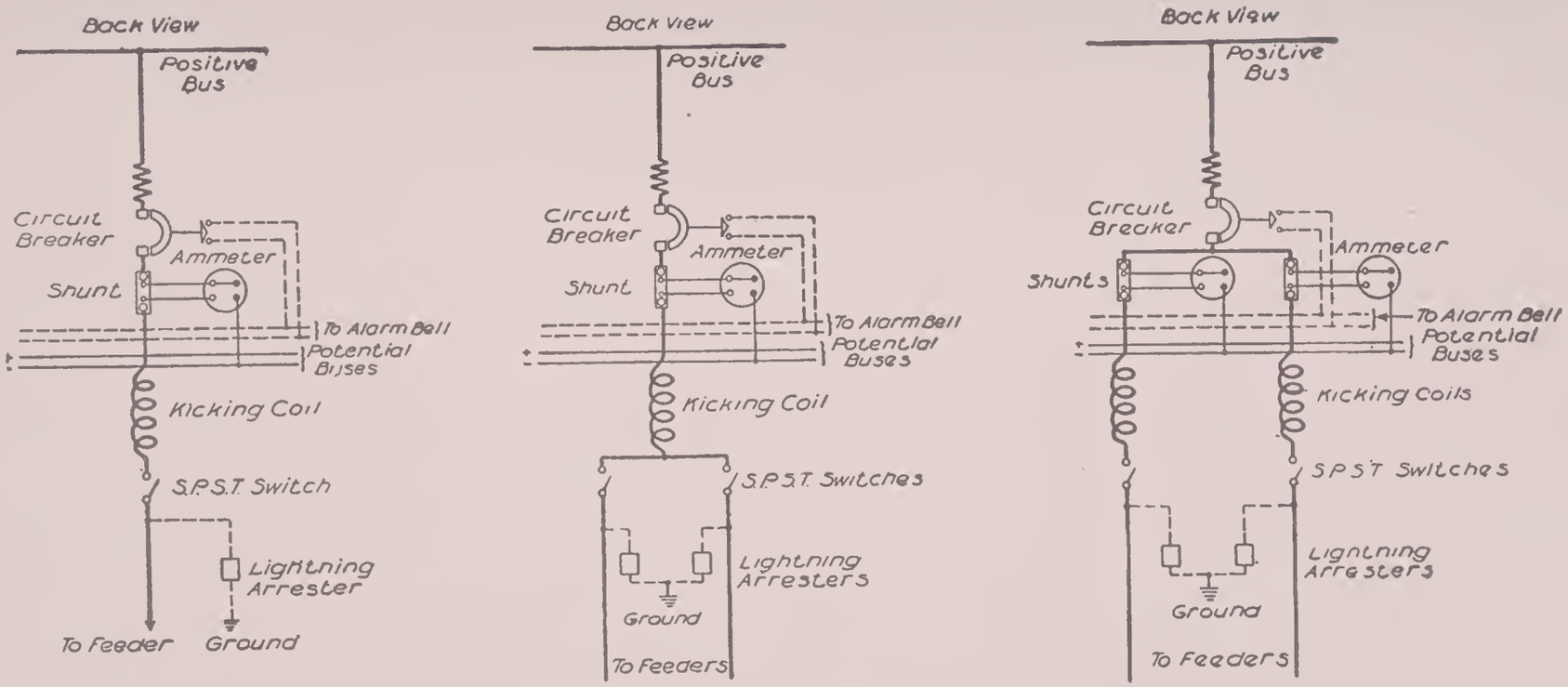


Fig. 287. Three Styles of D. C. Feeder Panels.

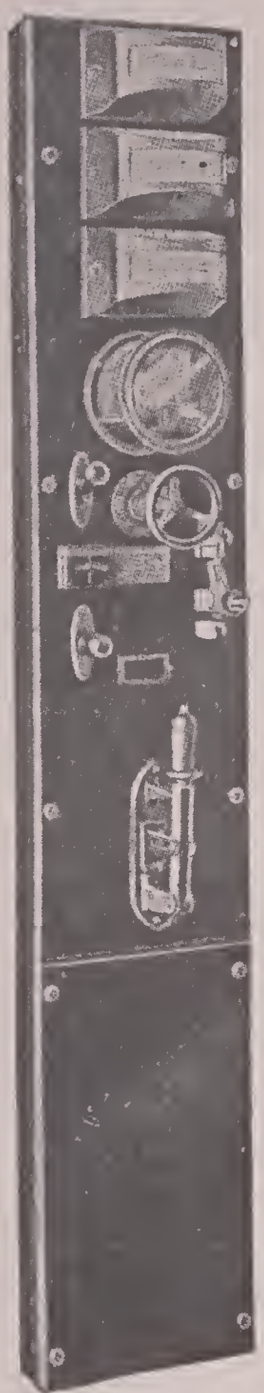


Fig. 288.
A. C. Generator Panel.

any currents flowing between the alternators which are operating in parallel.

The engine governor switch is to operate the motor which temporarily controls the governor on engine or turbine when their speeds are being altered to bring two alternators into synchronism or adjusting the division of load when operating in parallel.

The generator oil switch has no automatic overload release, as it is important to keep the generator in service during heavy short circuits caused by trouble on the transmission lines. When such short circuits occur, the generators are immediately relieved by the opening of the automatic line switches.

The diagrams for connecting up generator panels according as transformers are or are not used will be found in Figs. 289 and 290.

A. C. Outgoing Panel.

The panel on left of Fig. 291 contains:

3 Horizontal edgewise ammeters.

1 T. P. S. T. oil switch, with overload release.

3 Current transformers.

Three ammeters—one for each phase—are furnished for each line, to facilitate the detection of unbalancing due to open circuits or leakage. With balanced loads,

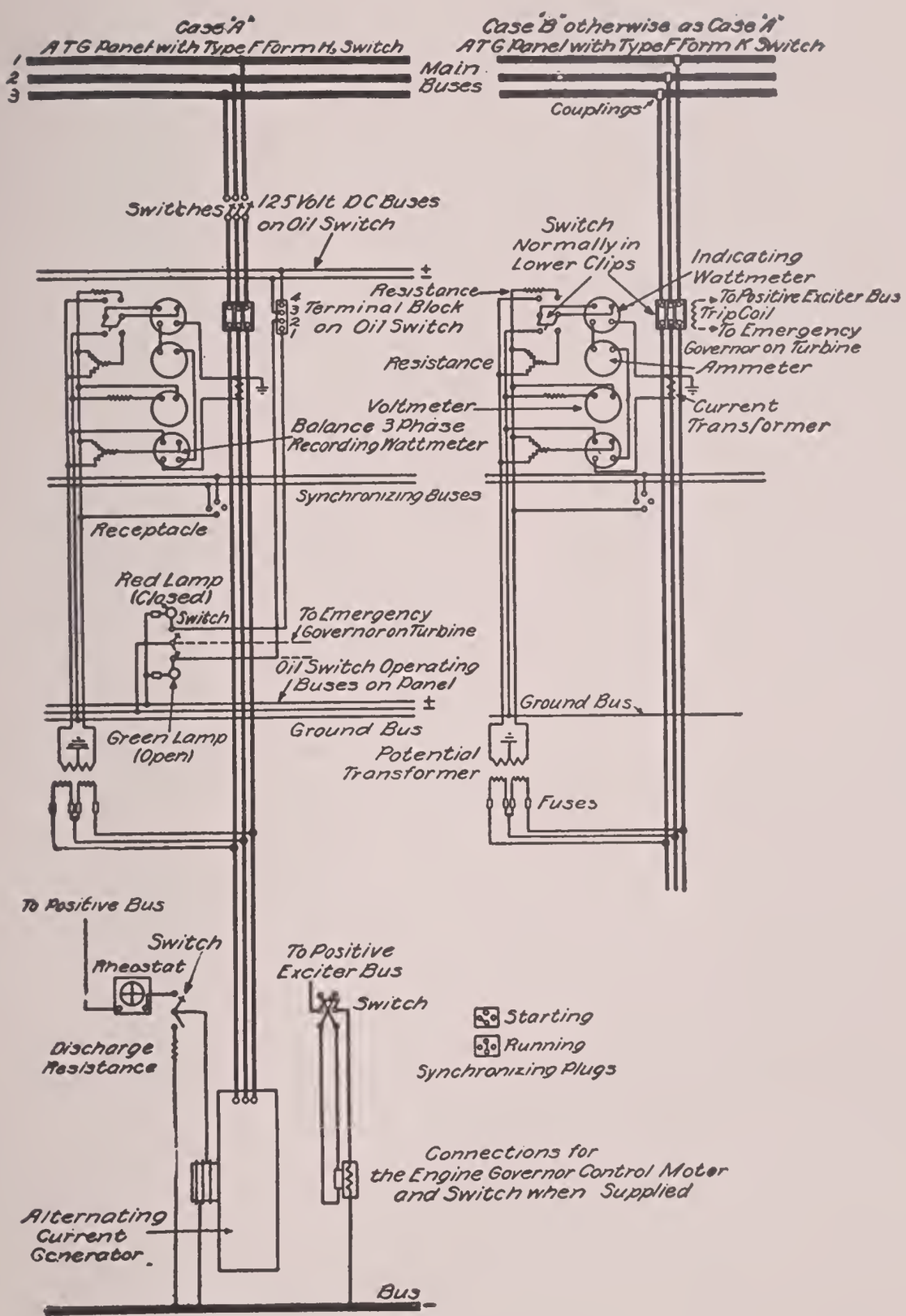
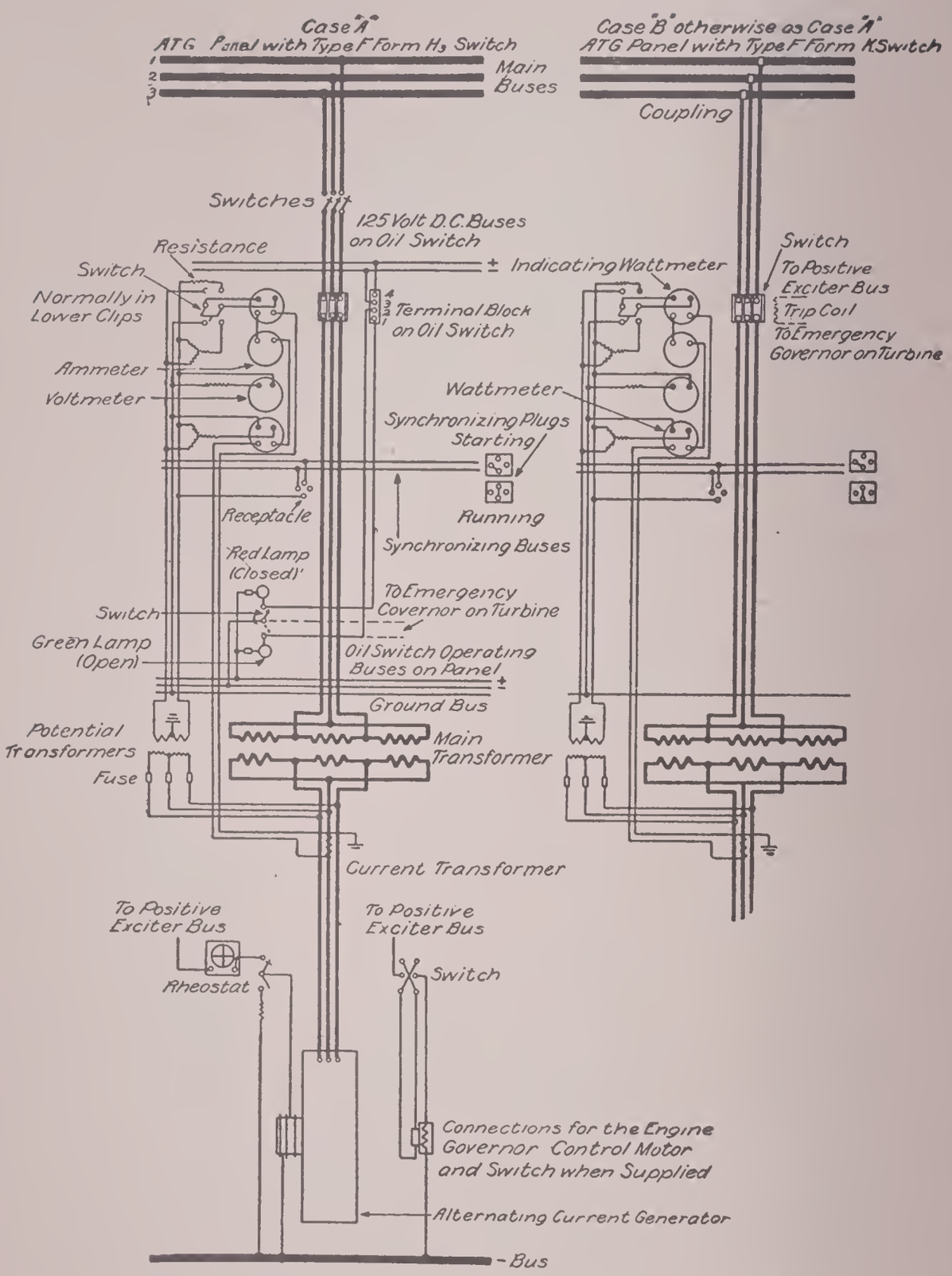


Fig. 289. A. C. Generator Panel without Step-up Transformers.



ALTERNATING CURRENT GENERATOR PANEL FOR GENERATOR WITH STEP-UP TRANSFORMER

Fig. 290. A. C. Generator Panel for Generator with Step-up Transformer.

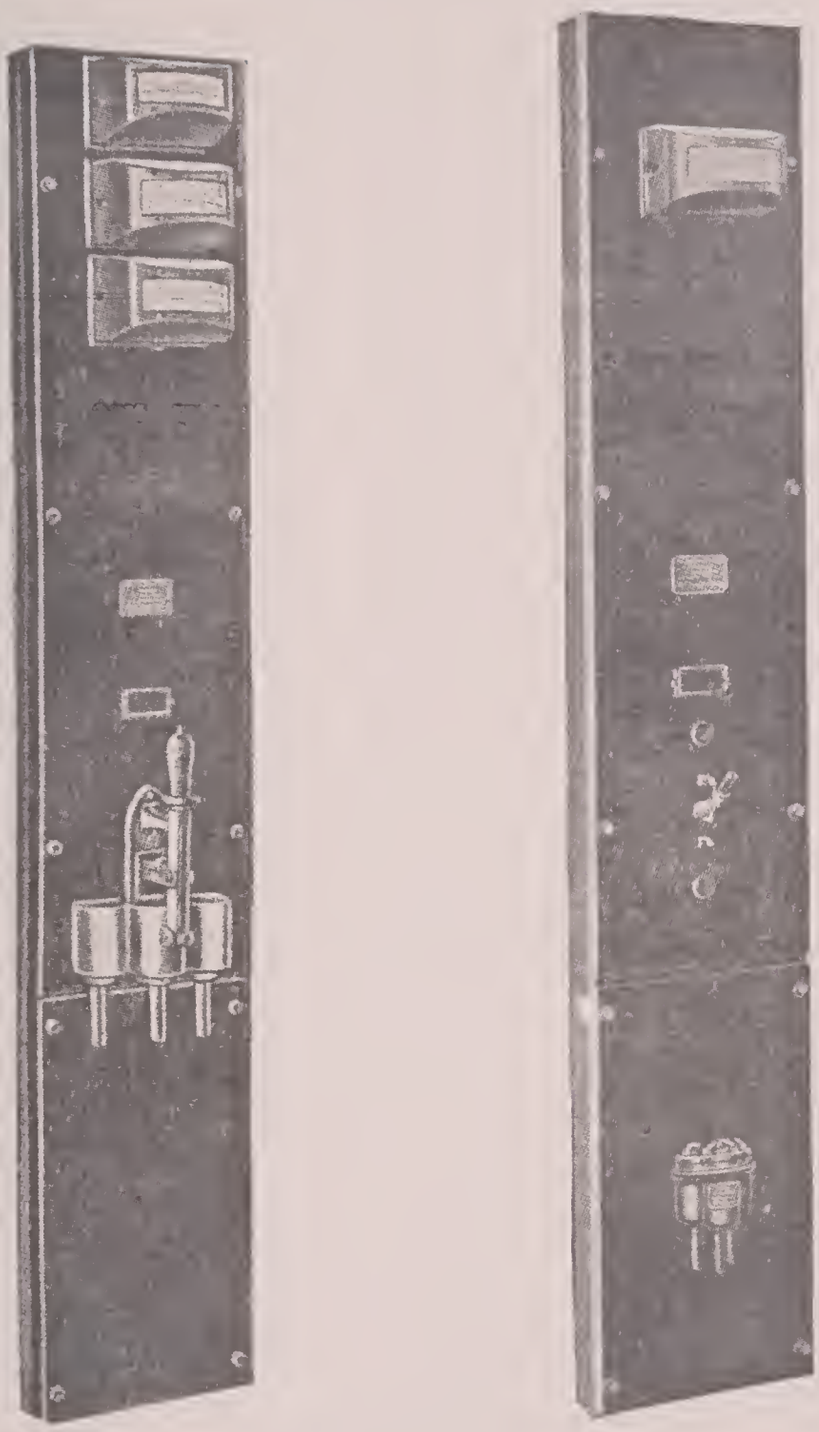


Fig. 291. A. C. Outgoing Line Panels.

the ammeter pointers should show equal deflections under normal conditions. As the ammeters are arranged in a perpendicular row any variation in the deflections of the pointers is readily detected.

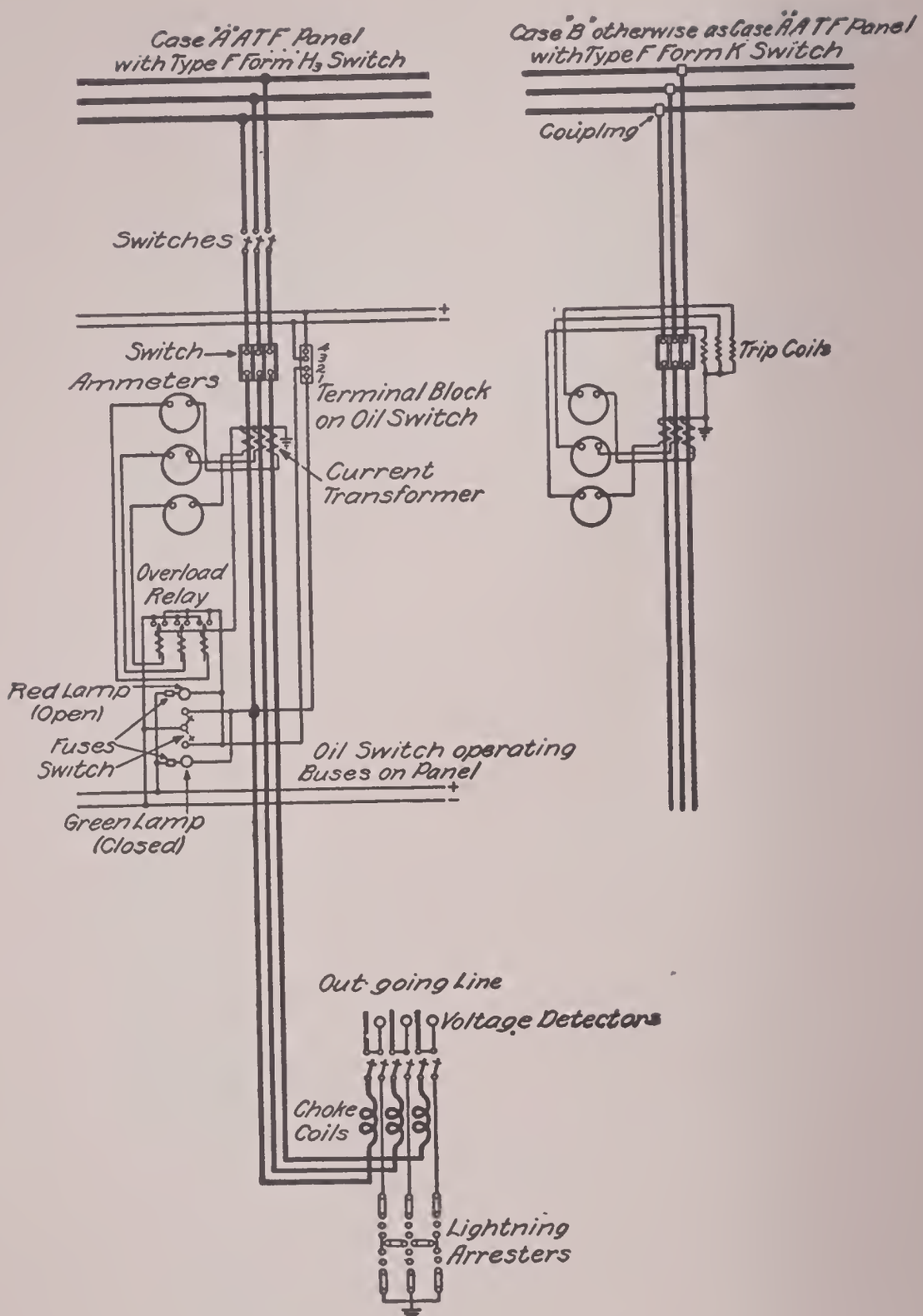


Fig. 292. A. C. Outgoing Line Panel.

The current transformers serve to operate the ammeters and the automatic release on oil switches.

The panel on right of Fig. 291 has but one ammeter and merely has the handle for operating the oil switch. The actual switch being in a brick compartment at rear of panel. The overload relay (3 pole) which trips the oil switch is at base of panel.

Fig. 292 gives the electrical connections of panels in Fig. 291.

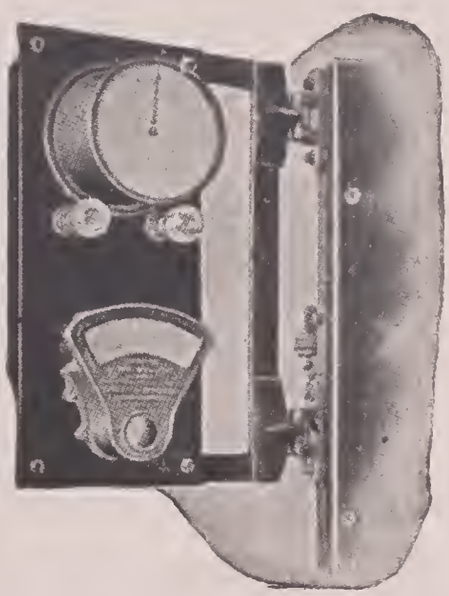


Fig. 293. Synchronism Indicator and Exciter Voltmeter on Swinging Bracket.

The swinging bracket of Fig. 293 contains a synchronism indicator, two lamps for synchronizing (practically a duplicate set of synchronizers) and a voltmeter for the station exciter *generator.

To use the synchronism indicator put one plug in on panel of a generator which is running and the other plug in the panel of the generator which is starting.

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*D. C. Generator furnishing current for fields of alternators.

Fig. 294. Main Station Switchboard for One A. C. Generator and One Outgoing Line.

Fig. 294 shows a complete switch board of one generator panel in center, a panel for one outgoing line on the right, an excited panel on left, with the swinging bracket on extreme left.

Such a switch-board would be extended towards the right indefinitely, as more lines were put on the station, by the addition of more outgoing line panels.

Exciter Panel.

Each exciter panel is equipped with:

1 Thomson feeder type ammeter.

1 Hand-wheel for operating rheostat.

1 Two-point potential receptacle connected to voltmeter.

1 S. P. S. T. positive lever switch, with fuse mounted back of panel.

One Exciter Panel in every switch board is furnished with the following additional switches: (as in Fig. 295.)

2 S. P. S. T. lever switches, with fuses back of panel, for the control of station lighting and auxiliary circuits.

On the frame of each exciter there are required the following switches, mounted on a common slate base:

1 S. P. S. T. negative lever switch.

1 S. P. S. T. lever switch for equalizing.

Fig. 295, Exciter Panel Auxiliary Lighting Switches on Sub-Base.

The exciter panels are designed single pole, *i. e.*, only the positive leads of the generators are connected to the switch-board panels and only the positive bus-bar is mounted back of them. The negative and equalizer leads are connected through their switches to the nega-

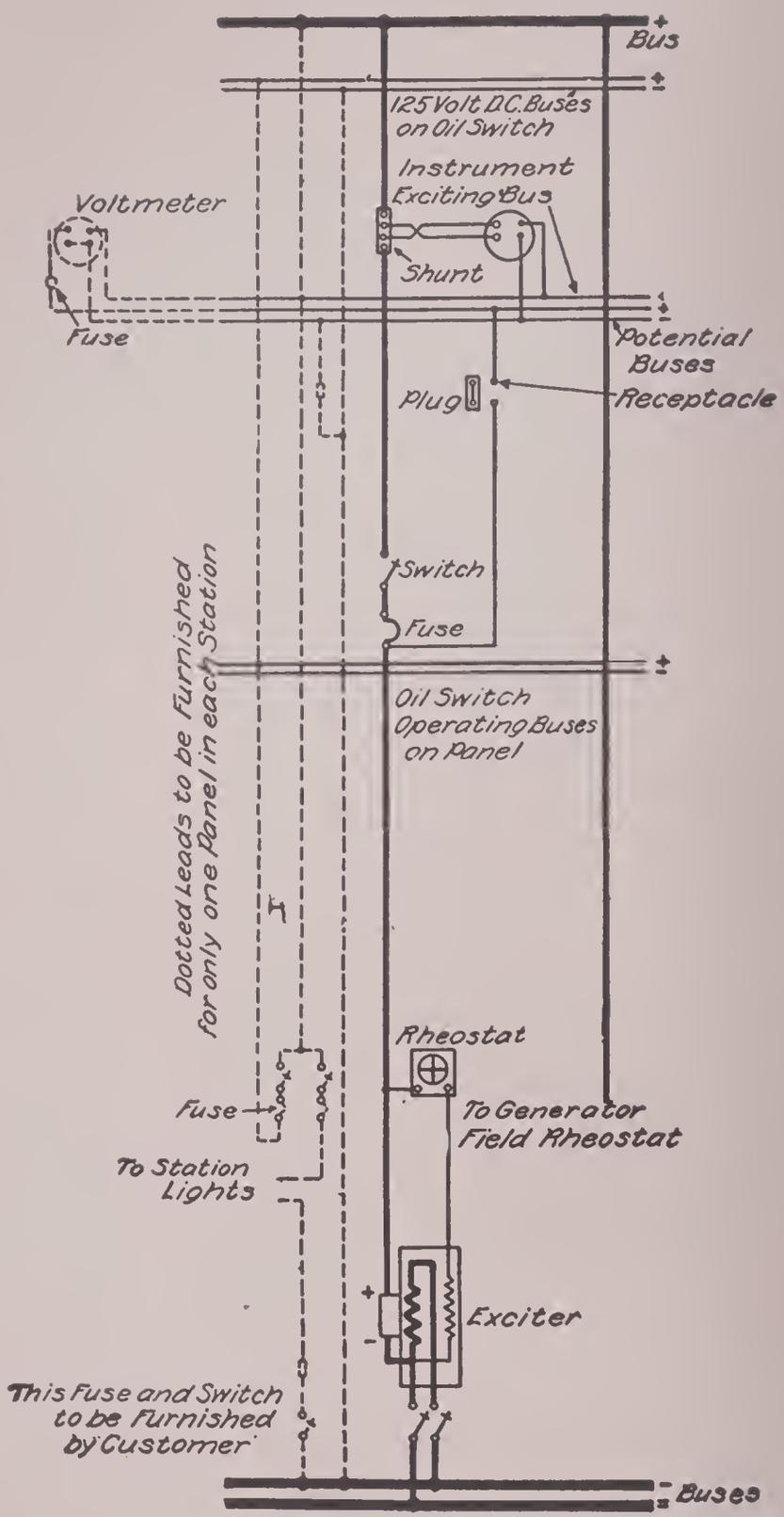


Fig. 296. Exciter Panel.

tive and equalizer bus-bar, which are placed under the floor near the exciters. With the bus-bars of opposite polarity so widely separated there is practically no chance of short circuit of the exciter connections. The positive field leads of the alternators are carried to the panels, while the negative field leads are permanently connected to the negative exciter bus-bar.

Fig. 296 will give the electrical connections of an exciter panel.

Fig. 297. Starting Panel for D. C. Blower Set.

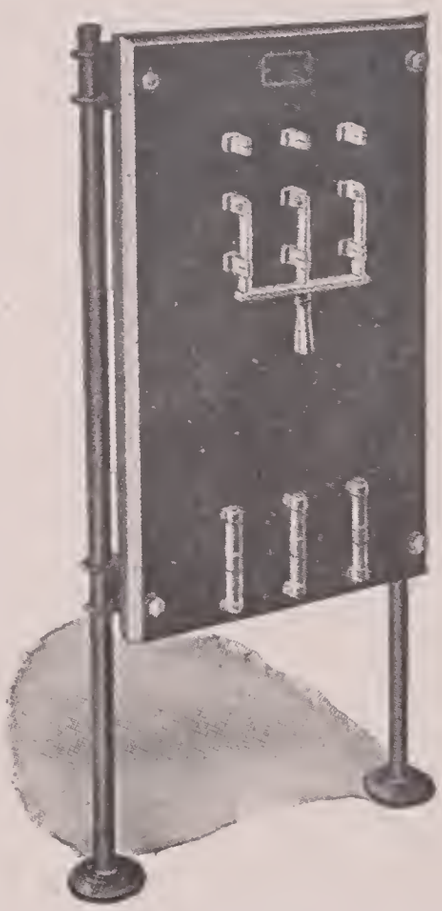


Fig. 298. Main Switch Panel for A. C. Blower Set.

The blower motors running the blowers which cool transformers are of the 3 phase induction type or D. C. shunt motors.

The D. C. motors are started by the regular starting box, Fig. 297.

The current to an induction motor is controlled by a switch like Fig. 298, if from auxiliary low voltage buses or from an oil switch on a panel like Fig. 299, if full station voltage is used.

The actual starting is done by a switch as in Fig. 300, which is between secondaries of transformers or reactance coils and the induction motor.

Fig. 301 shows connections of an induction motor to main buses, using an oil switch and a starting switch.

The operation of several sub-stations on a single line is generally recognized as good practice, especially for interurban systems on which the traffic is not very dense.

To insure continuity of service in the event of line trouble, it is expedient to sectionalize the line at every sub-station that is located at an intermediate point of the line. This sectionalizing is accomplished at each intermediate station by carrying the incoming line to the bus-bars through the air break disconnecting switches which are installed in connection with the arresters, and by carrying the outgoing line through an oil switch. In case of line trouble, this arrangement allows all sections of the line between the generating station and any section on which the trouble occurs to be operated continuously. The power is automatically cut off from the section in trouble by an oil switch in the outgoing line panel equipment of the sub-station at the generating station end of the section, so that the air break disconnecting switches in the sub-station at the other end of the section need never be opened under load.

When duplicate transmission lines are used, two in-

coming line panels and two outgoing line panels are recommended for each intermediate sub-station. The installation of these individual panels facilitates the disconnection of either line of any section and the continuance of the service over the other line of the section without any interruption.

The arrangement of switchboard panels in sub-stations differs from the generating station arrangement, in that the alternating current panels are, preferably, installed individually near their several line or transformer oil switches, thus greatly simplifying the high tension wiring and the oil switch operating mechanisms; while the continuous current panels are grouped into a single switchboard conveniently located. The location of the alternating current panels, transformers, oil switch cells, continuous current switchboard, and machines, as shown in Figs. 260, 261 and 262, is suitable for a 13,200 volt 3 phase sub-station.

Standard sub-station line panels are equipped as follows:

A. C. Incoming Line Panel.

These are only used when lines are in duplicate, and are shown in Fig. 299.

A. C. Outgoing Line Panel.

These are necessary in every sub-station except the terminal one. This panel is shown on left of Fig. 291.

The ammeter on incoming panel must be able to show all the current ever drawn by its own sub-station and those beyond. The capacity of the three ammeters on any outgoing line panel, however, need only be large

Fig. 299. Oil Switch A. C. Panel for Incoming Line Motor Driving Exciter or A. C. Side of Rotary.

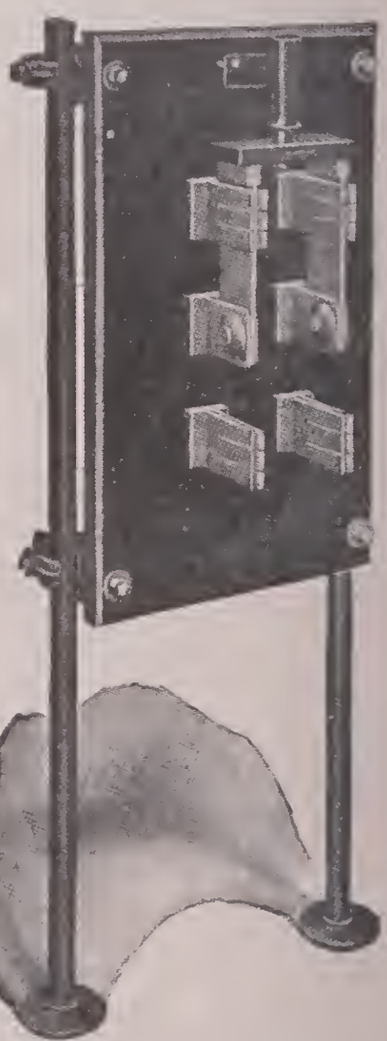


Fig. 300. Induction Motor or Rotary Starting Panel.

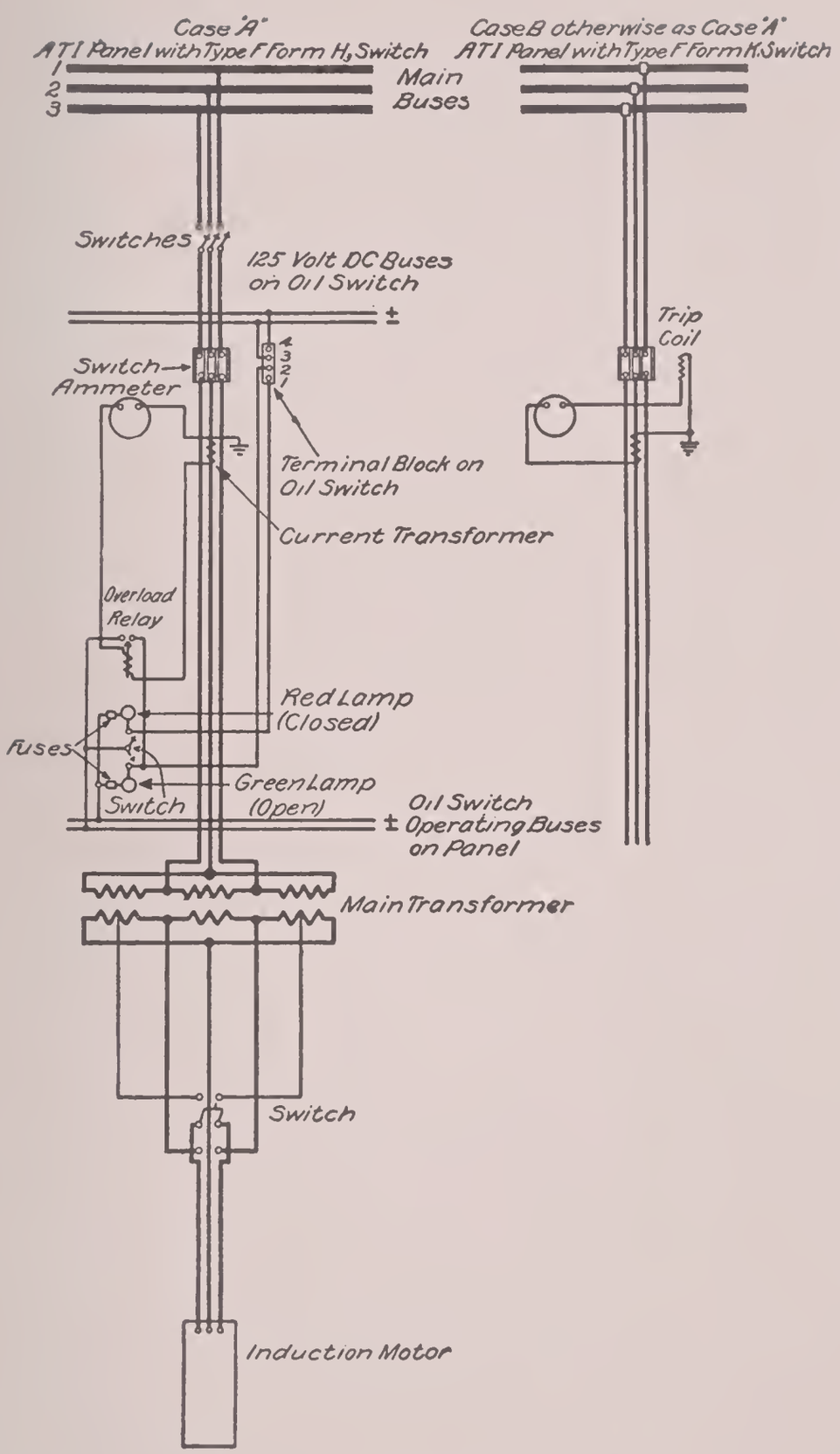


Fig. 301. Induction Motor Panel.

enough to read the maximum load on the line beyond the sub-station in which the panel is installed. As already stated for the outgoing panels of the generating station, three ammeters are furnished in order to indicate, by their unbalanced readings, any open circuit leakage on the outgoing line.

A. C. Rotary Converter Panel.

The panel controlling the intake of the rotary is shown in Fig. 291 (on right). It contains:

1 horizontal edgewise ammeter.
1 T. P. S. T. overload relay for oil switch.
1 current transformer.

Three-Phase Rotary Starting Panels.

In Fig. 300 is shown this panel. The switch is used for starting the converter by connecting two of the three converter leads, first to half-voltage taps and then to the full voltage terminals of the transformer. The third converter lead is permanently connected to the third terminal of the transformer.

Six-Phase Rotary Starting Panels.

As shown in Fig. 302 contains 2 T. P. D. T. lever switches.

These switches are used for starting the converter by connecting three of the six converter leads, first to one-third voltage taps, next to two-thirds voltage taps, and

finally to the full voltage terminals of the transformer. The other three converter leads are permanently connected to the remaining three transformer terminals.

Position of Panels.

The A. C. incoming line panels are connected between the high tension bus-bars and the three-phase primaries of the step-down transformers, and are, therefore, suitable either for three or six-phase converters. Convert-

Fig. 302. Six-Phase Rotary Starting Panel.

ers of capacities up to 400 kilowatts are usually three-phase, and above that capacity, six-phase. The secondaries of the transformers are not carried to the main switchboard but are connected through separately mounted starting panels to the converters. The dimensions of rotary converter starting panels vary with the capacity

Fig. 303. Rotary Output Panel.

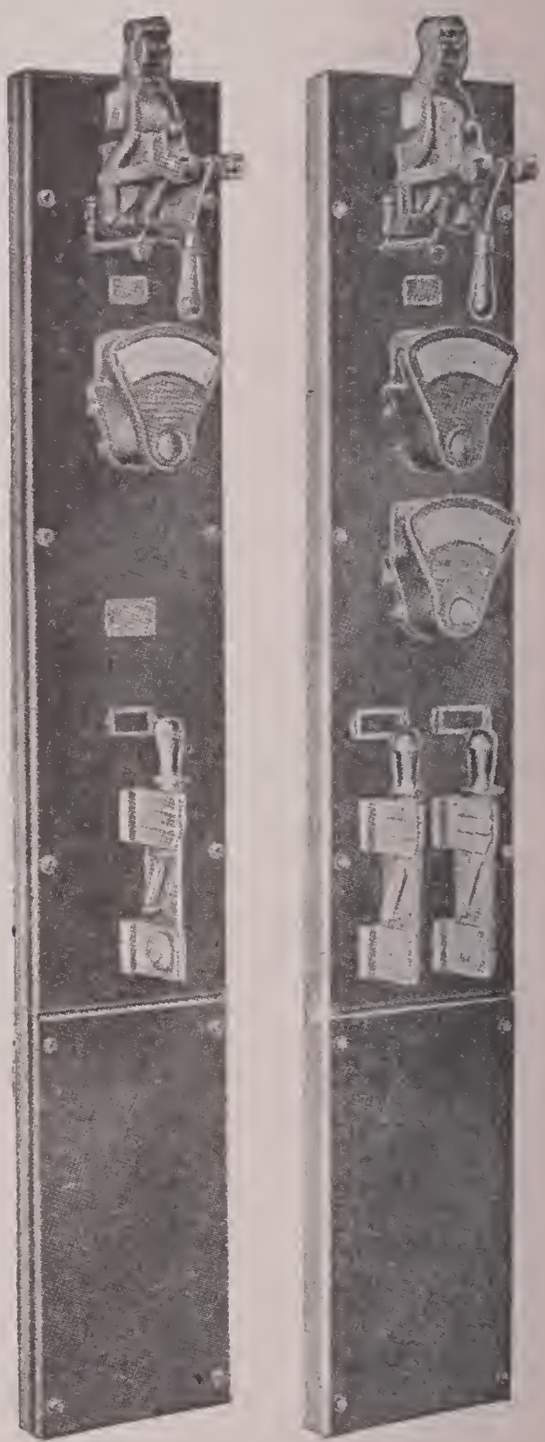


Fig. 304. D. C. Feeder Panels.

of the converters, but they are of suitable size for mounting near the latter. In most cases where compound wound converters with reactive coils are used, the coils are connected between the transformer secondaries and the converters, and the starting panels are mounted on top of the reactive coil casings.

Rotary Output Panels.

These panels are the same as D. C. generator output panels and are shown in Fig. 303.

The circuit breaker is furnished with a low voltage release coil, which trips when the voltage drops to approximately half of its normal value, and with a telltale switch, for connection to an alarm bell which will ring when the breaker opens automatically. To prevent racing of the converter caused by accidental disconnection on the alternating current side, an adjustable speed limiting switch is mounted on the converter shaft. This speed limiting switch operates to short circuit the low voltage release coil when the speed of the converter increases a certain degree above normal, thereby tripping the breaker and disconnecting the converter from the continuous current bus.

The continuous current rotary converter panel is connected in the positive side of the circuit, and the negative side is permanently connected to the grounded negative bus, which is run along below the machine. The equalizing switch, and the switch for opening the shunt to the series field, required for a compound wound rotary converter, are mounted directly on frame of machine.

The advantages of equalizing on negative side and of using single pole switches has been discussed under generators.

D. C. Outgoing Line Panels.

The panels for one and two circuits are shown in Fig. 304.

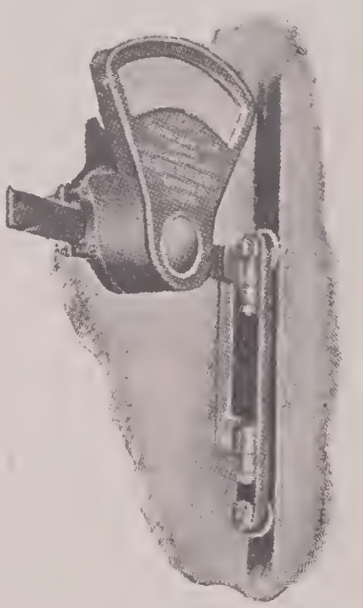


Fig. 305. Voltmeter Bracket.

Placing Rotaries in Service.

After a rotary converter has been started from the alternating current ends and builds up with the proper polarity, the following procedure should be followed to throw the direct current end in parallel with other machines running:

First—Close equalizer switch (on machine).

Second—Close circuit breaker (on panel).

Third—Insert potential plug in receptacle and regulate voltage.

Fourth—When the proper voltage is obtained close positive switch (on panel).

Swinging Bracket for Voltmeter.

As shown in Fig. 205 a swinging bracket is provided to be mounted at end of board, carrying:

1 Thomson illuminated dial station type D. C. voltmeter.

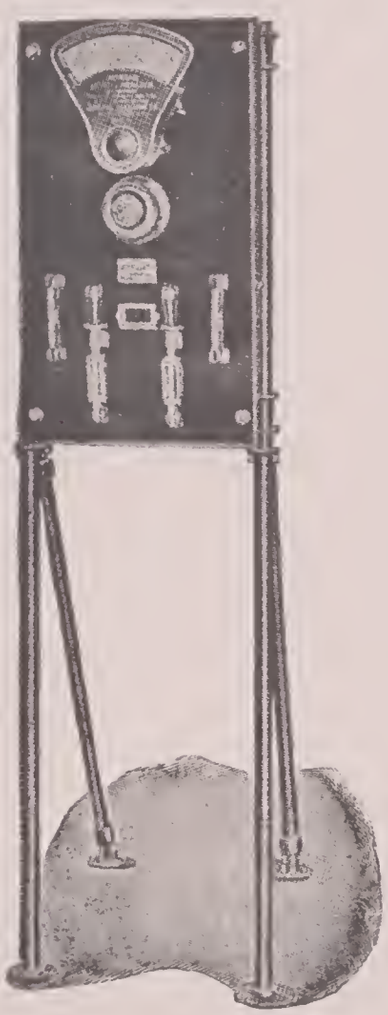


Fig. 306. Storage Battery Panel.

1 plug for insertion in receptacles on the rotary output panels, thus connecting the voltmeter to the particular machine.

If the rotary when started from the A. C. side comes up with polarity reversed, the voltmeter will swing back of zero.

The polarity of the converter can be corrected by operating the four pole double throw *field break-up reversing switch,* which is mounted on the frame of the converter and included in its equipment. This field reversing switch stands normally in its "up" position, and the operation of throwing it into the "down" position reverses the field magnetization. When the voltmeter needle indicates that the throwing of the switch into the "down" position has established correct polarity, the switch should immediately be thrown back into the "up" position, thereby connecting the field correctly for service.

The operation just described should be performed while the alternating current side of the converter is connected to the low voltage taps of the transformer. When the voltmeter indicates the correct polarity, the converter may be connected to the full voltage terminals of the transformer. The continuous current voltage may then be adjusted by means of the field rheostat, and the machine thrown on the continuous current bus.

When motor operated oil switches are installed in the sub-station, a *storage battery* is used as a source of power for the small 110 volt series motors which operate the switches.

The storage battery consists of:

55 cells, giving 110 volts, the type and capacity of the cells depending upon the number of switches to be operated.

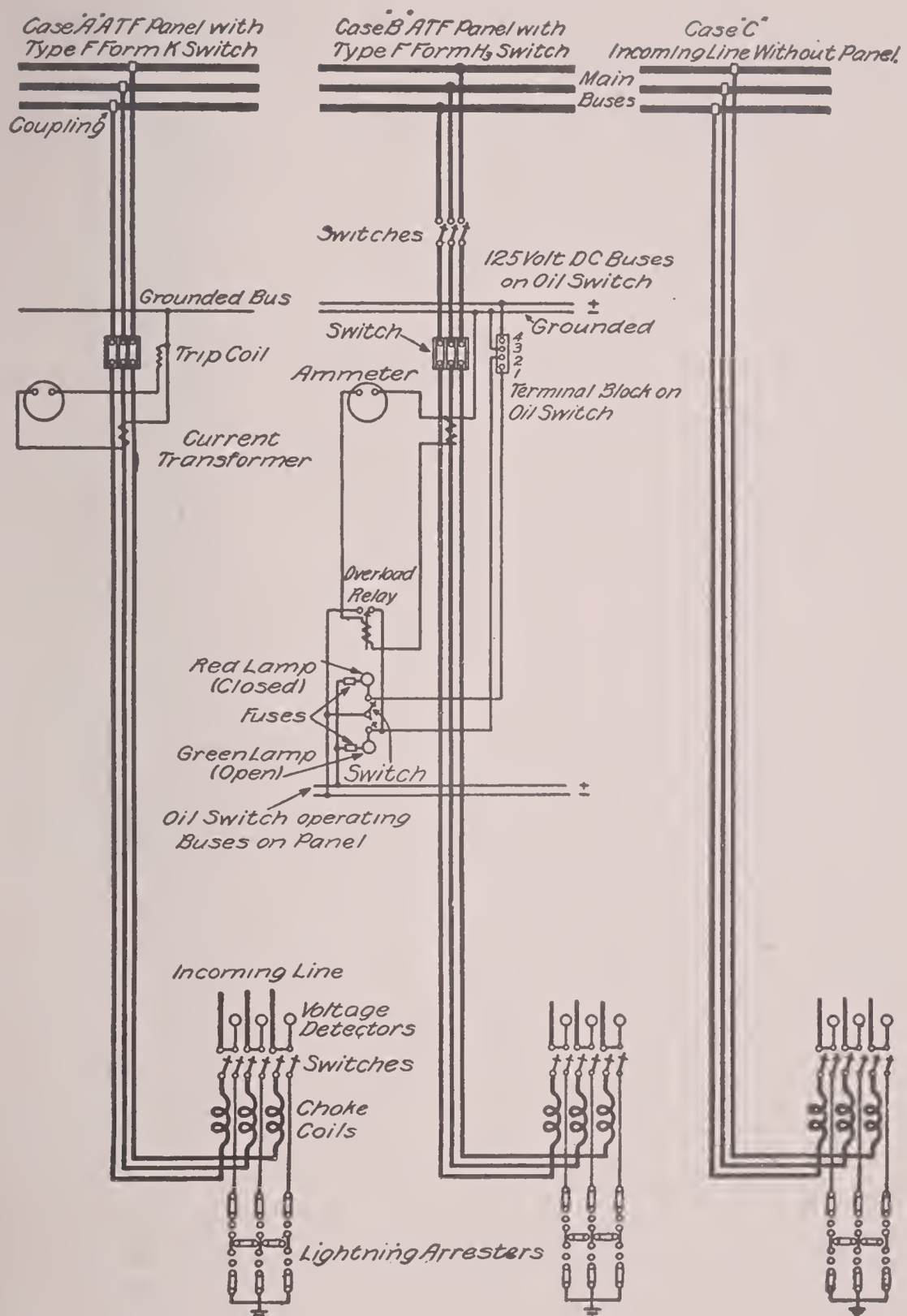


Fig. 307. Outgoing A. C. Line Panel.

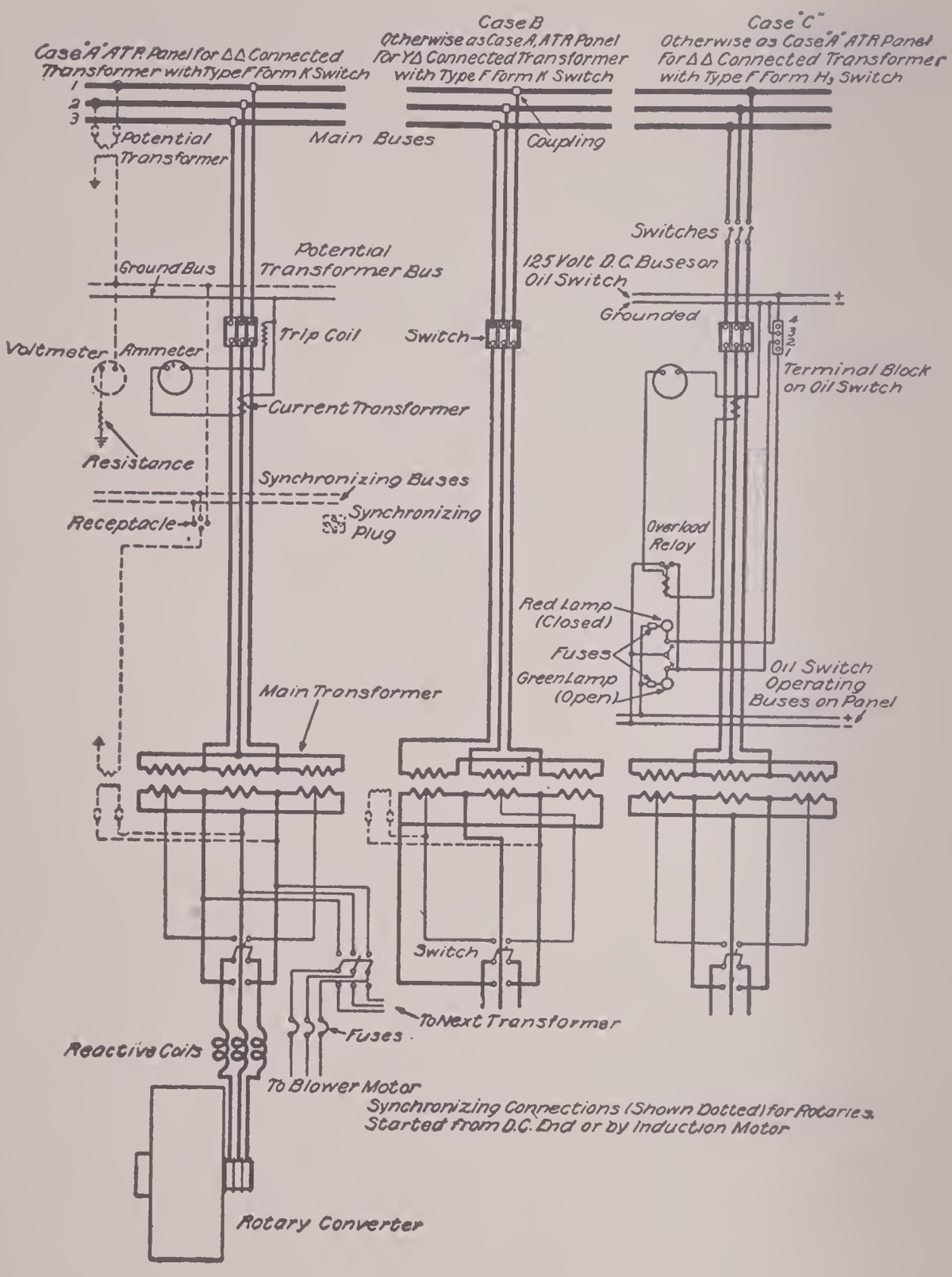


Fig. 308. A. C. End of Three-Phase Rotary.

Storage Battery Panel.

As shown in Fig. 306 contains:

1 Thomson feeder type ammeter, with zero at center of scale.
1 Rheostat.
2 S. P. S. T. quick-break switches.
2 enclosed fuses.

The battery is charged by connecting it in series with the rheostat across the 600 volt bus-bars. The rheostat is provided with a dial switch for regulating the charging current.

Blower Motor Panels

Are required for controlling the induction motor blower sets, which are used with air blast transformers. Each panel, as shown in Fig. 298, contains:

1 T. P. D. T. lever switch.
3 enclosed fuses.

The motors are usually wound for 350 volts, and are operated from the secondary side of the power transformers. The panels are located near the blowers.

As the transformers are not connected in parallel on the low tension side, the double-throw switch is furnished for connecting either of the duplicate blower motors, which are usually furnished, to whichever bank of transformers happens to be in use, as already described for the generating station.

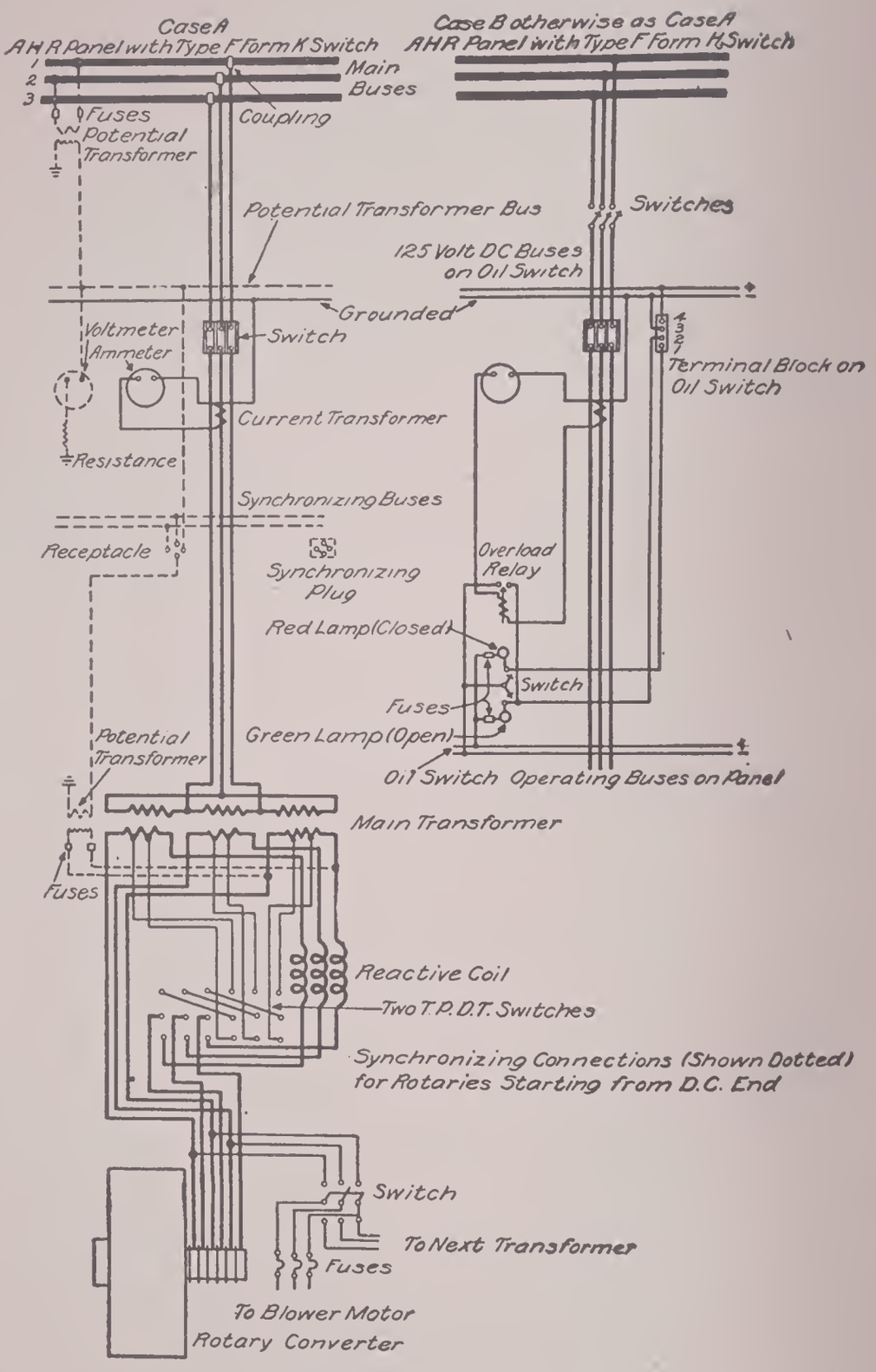


Fig. 309. A. C. End of Six-Phase Rotary.

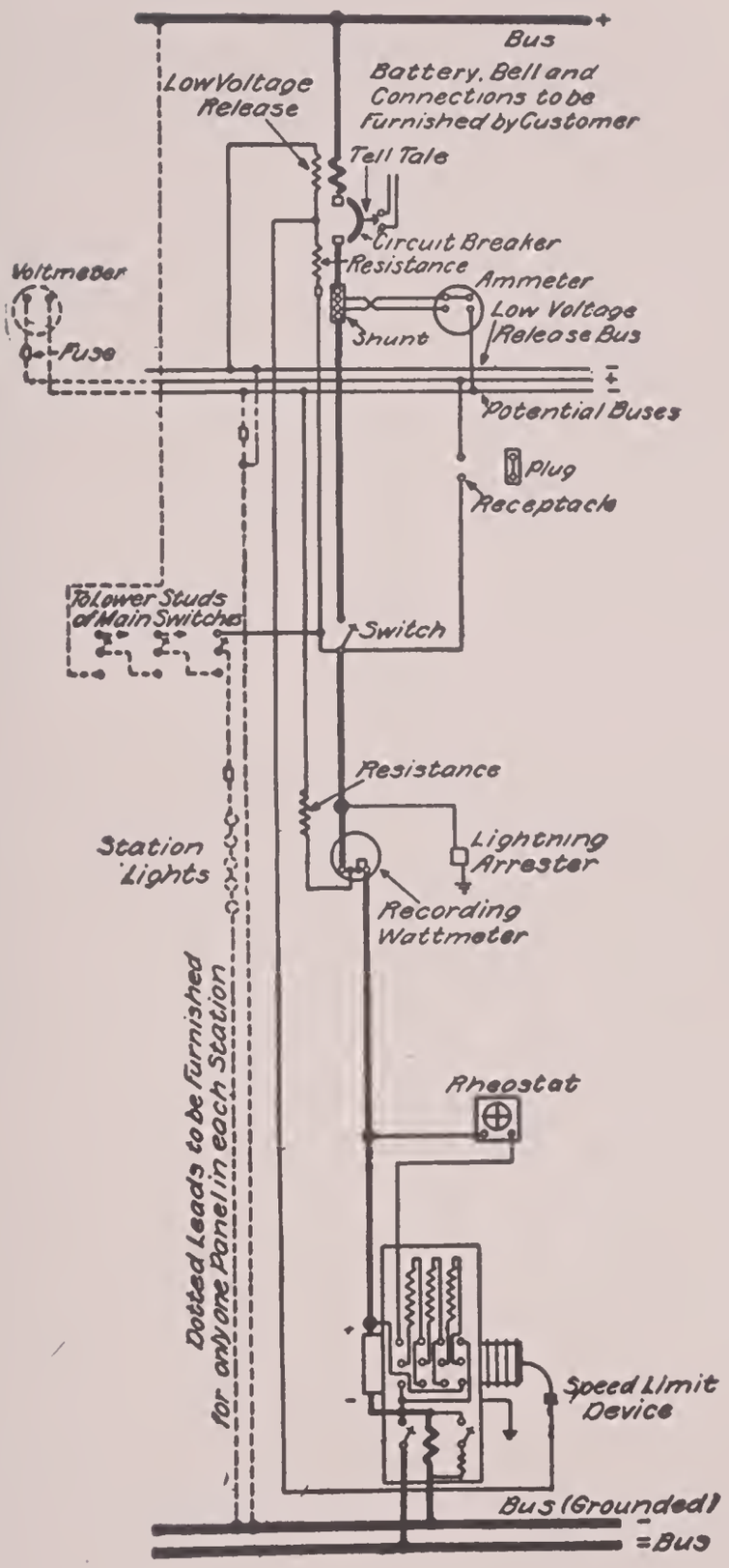


Fig. 310. Rotary Output Panel.

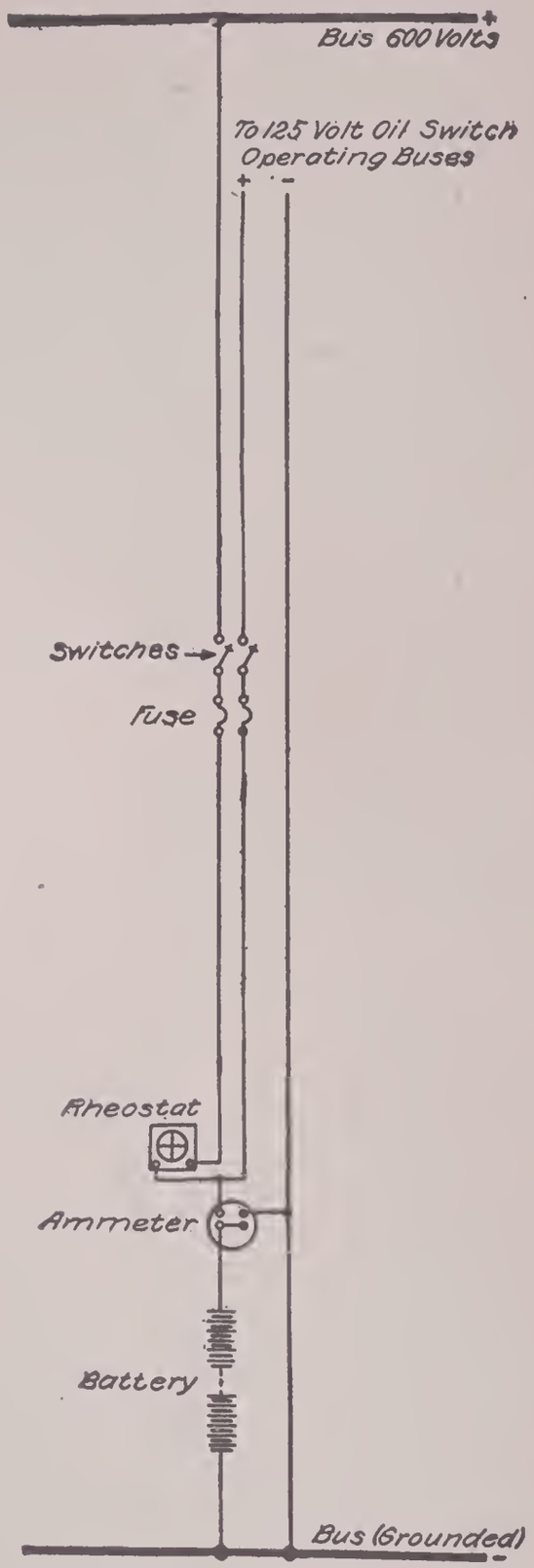


Fig. 311. Storage Battery Panel.

Electrical Connections of Panels.

A. C. incoming lines are shown in Fig. 307.

Connections for a three-phase rotary high voltage panel, low voltage starting panel and blower motor panel are shown in Fig. 308, while similar panels for six-phase rotaries are shown in Fig. 309.

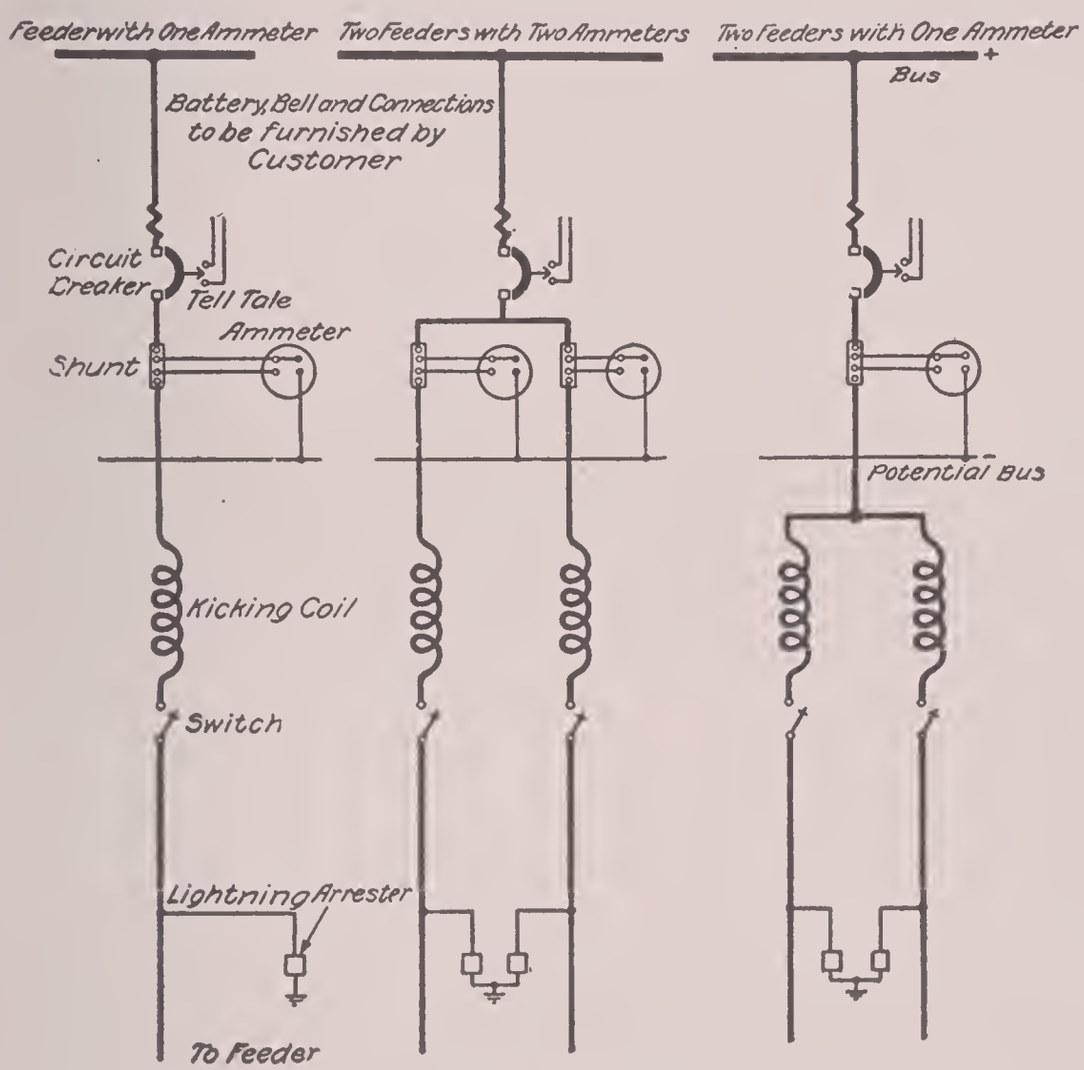


Fig. 312. D. C. Feeders.

The connections of a rotary panel are given in Fig. 310.

The storage battery panel is shown in Fig. 311.

D. C. feeder panels are connected as shown in Fig. 312.

LESSON 32.

Details of Switchboard Equipment and Station Accessories.

Lever Switches of type shown in Fig. 313, are used only to close circuits. When used to open circuits the *Quick Break* type is used, shown in Fig. 277. Half

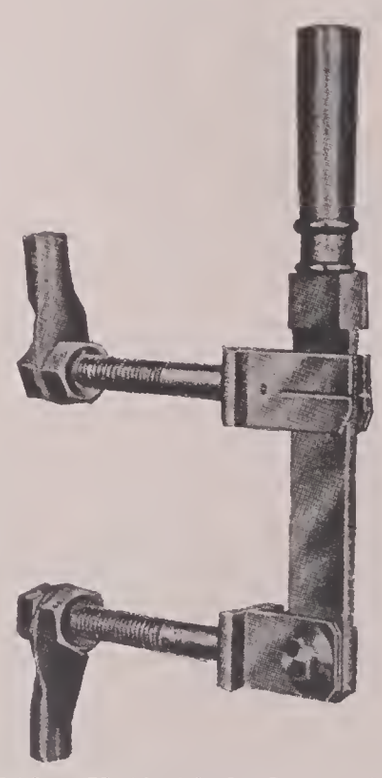


Fig. 313. Knife-blade Lever Switch.

the blade comes out of the clips when the handle is drawn back. This stretches the spring and the tension finally pulls the other half of blade out of clips at great speed, thus preventing much arc.

Field Discharge Switches, Fig. 278, are furnished only on the alternating current generator panels, and as they must be relied upon to shut down the generators under emergency conditions they embody several features of importance. As stated in the description of the generator panel equipment, the field switches are single pole and are furnished with clips for connecting a discharge resistance across the field when the latter is disconnected from its source of excitation, thereby preventing the generation of an excessively high potential, which might puncture the field insulation, when the field circuit is opened. The construction is such that in opening the switch the resistance circuit is closed before the field is disconnected from the exciter, while in closing the switch the resistance circuit is opened before the field is connected to the exciter. By this means all destructive arcing is avoided, for the field can never be broken without shunting it through the discharge resistance, yet the latter is not even momentarily connected across the exciter bus-bars while the switch is being closed.

Oil Switches. The severe conditions which must be anticipated on railway systems demand the use of switching apparatus which will protect the machines and lines from excessive overloads and short circuits without injury to the switches, as the latter must be in condition to put the machines back into service as soon as any temporary trouble has been remedied. These requirements are best met by reliable oil switches, properly installed in brick cells situated apart from the switchboard to prevent any local trouble from spreading.

In case of a dead short circuit on a feeder near the generating station, the current in the circuit which must

be opened reaches a maximum the value of which may be many times the normal capacity of the generators. The automatic feeder switches must be capable of breaking this maximum current instantaneously. The non-automatic switches, on the other hand, are not required to

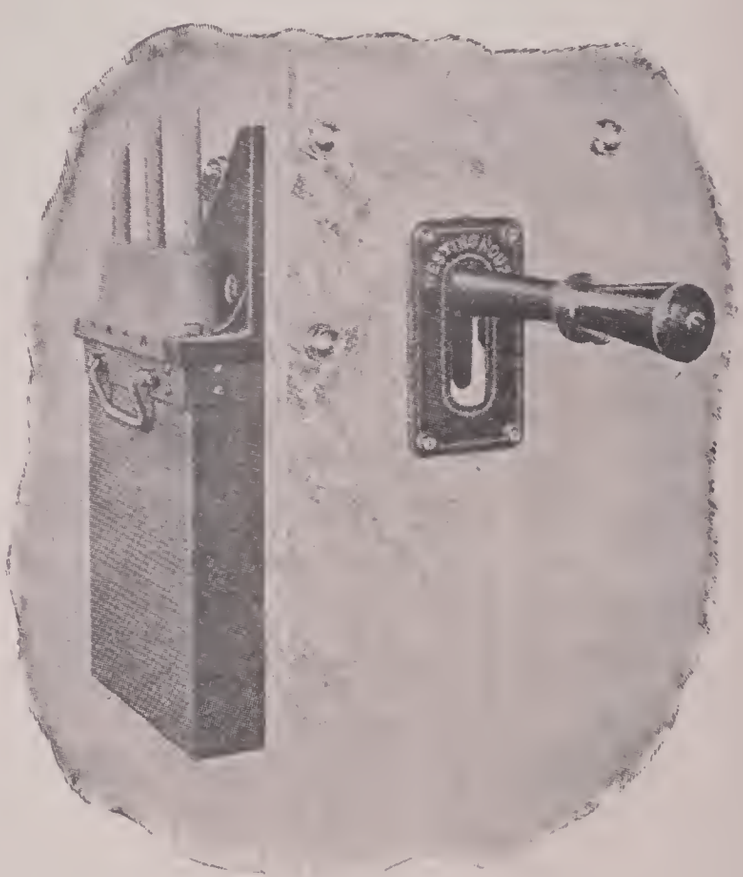


Fig. 314. Front View of Oil Switch.

open the maximum current, but must be capable of opening the load after the current has dropped to a value which the generator will maintain on short circuit.

Figs. 314 and 315 show the operating handle and the switch mechanism of a three pole oil switch.

A triple pole double throw oil switch for panel use is shown in Fig. 316.

It is often desired to have the switch at some distance from the panel on which it is controlled.

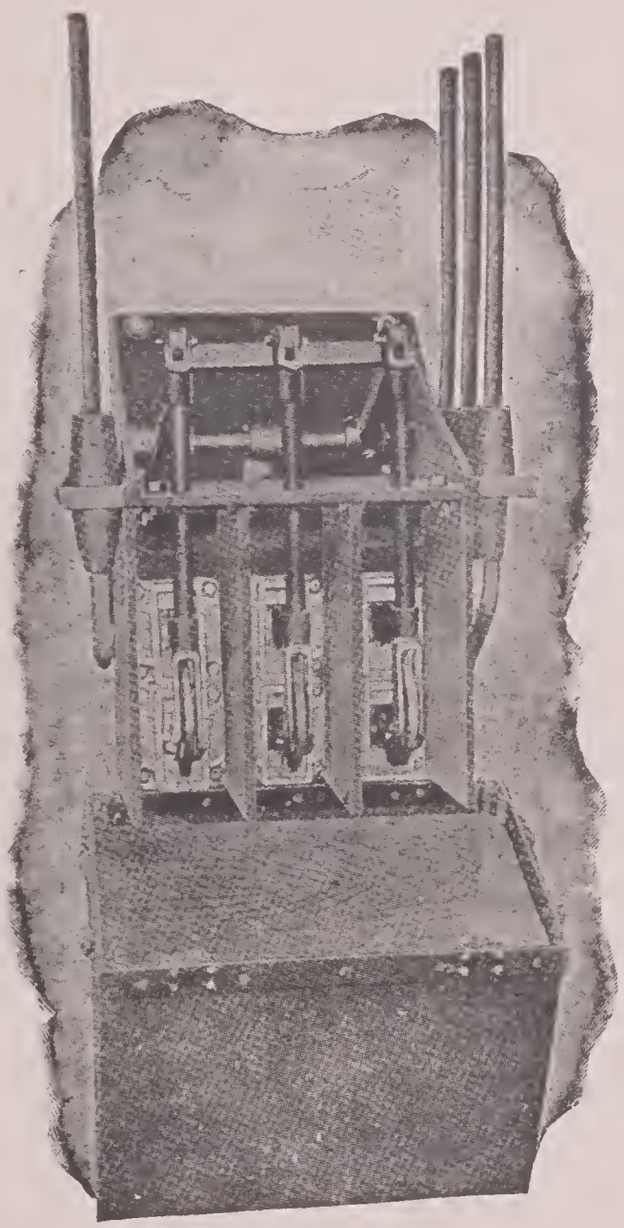


Fig. 315. Rear View of Oil Switch.

In Fig. 317 is shown a triple pole single throw 15,000 volt 300 ampere oil switch. It would be very unsafe to have this on the switchboard.

It is built into a three compartment brick cell at some distance behind board and controlled by a long rod running from lever on panel. This switch is of the non-automatic type, being used for a main generator switch.

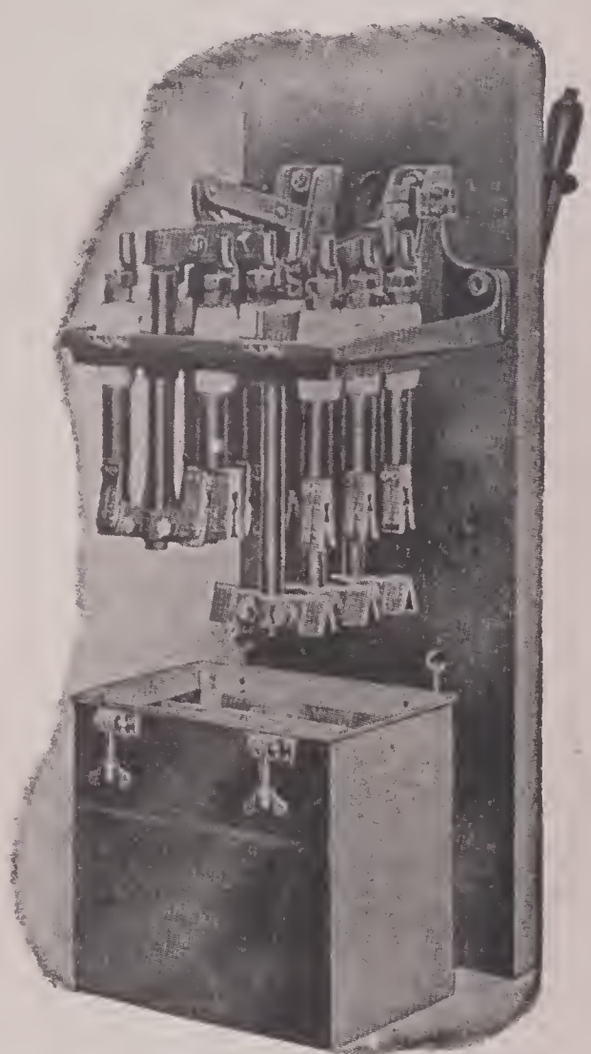


Fig. 316. Three Pole, Double Throw, Oil Switch.

Such switches, when used on transformers, are so far from the panel that some arrangement as in Fig. 318 is used.

Switches at a distance from the board may be controlled electrically if fitted with a tripping magnet and

closed by sending an attendant to the switch. This is very bad practice, as the time wasted and even possibility of closing wrong switch must be considered. The switch in Fig. 319 is operated by two magnets, the left hand one (not clearly shown) opening, the right hand one closing, switch. A small S. P. D. T. switch on panel

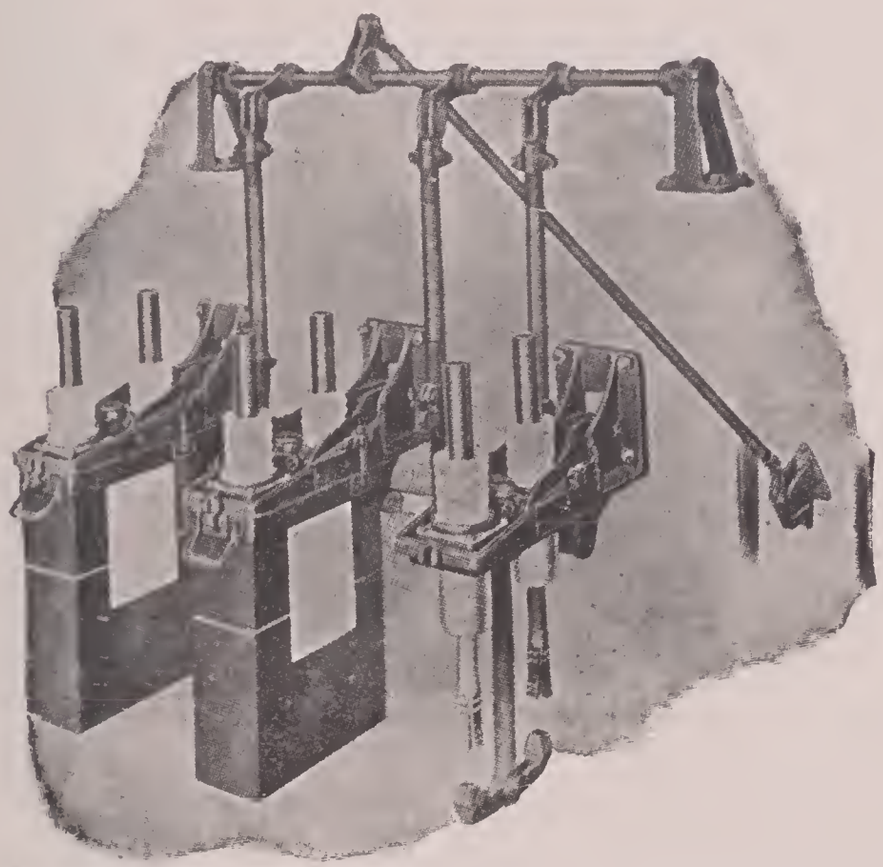


Fig. 317. Oil Switch 15,000 Volt, 300 Ampere Triple Pole, Single Throw. Brick Partitions Not Shown.

controls the two magnets. Large switches, as Fig. 320, are opened and closed by motors. For such a motor switch there will be on the panel:

1 S P. D. T. operating switch for the control of the oil switch motor.

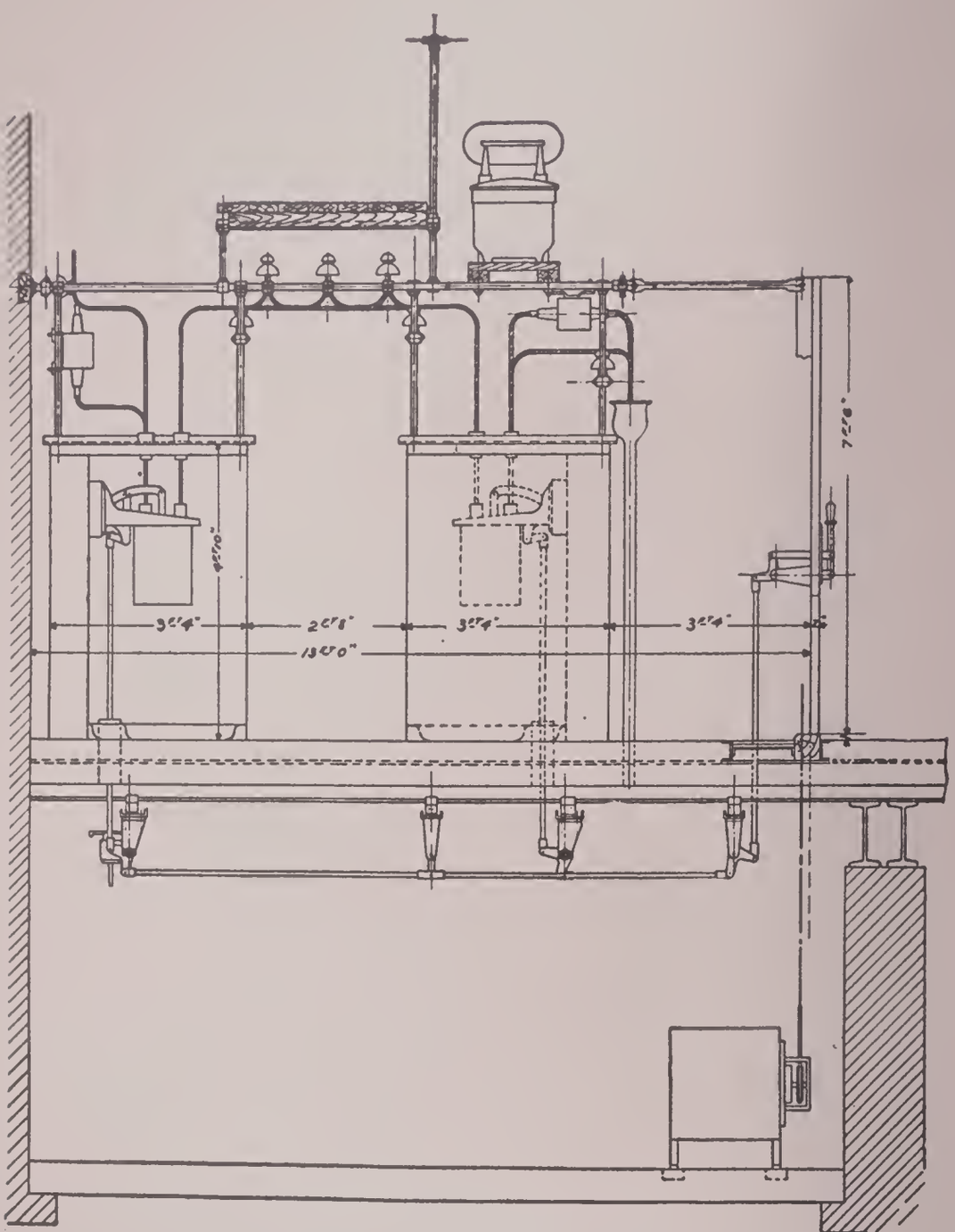


Fig. 318. Arrangement of Remote Control Lever Oil Switches.

2 miniature lamps, one with red and other with green bull's eye.

If the switches must open automatically there is provided in addition to the above:

1 overload relay.

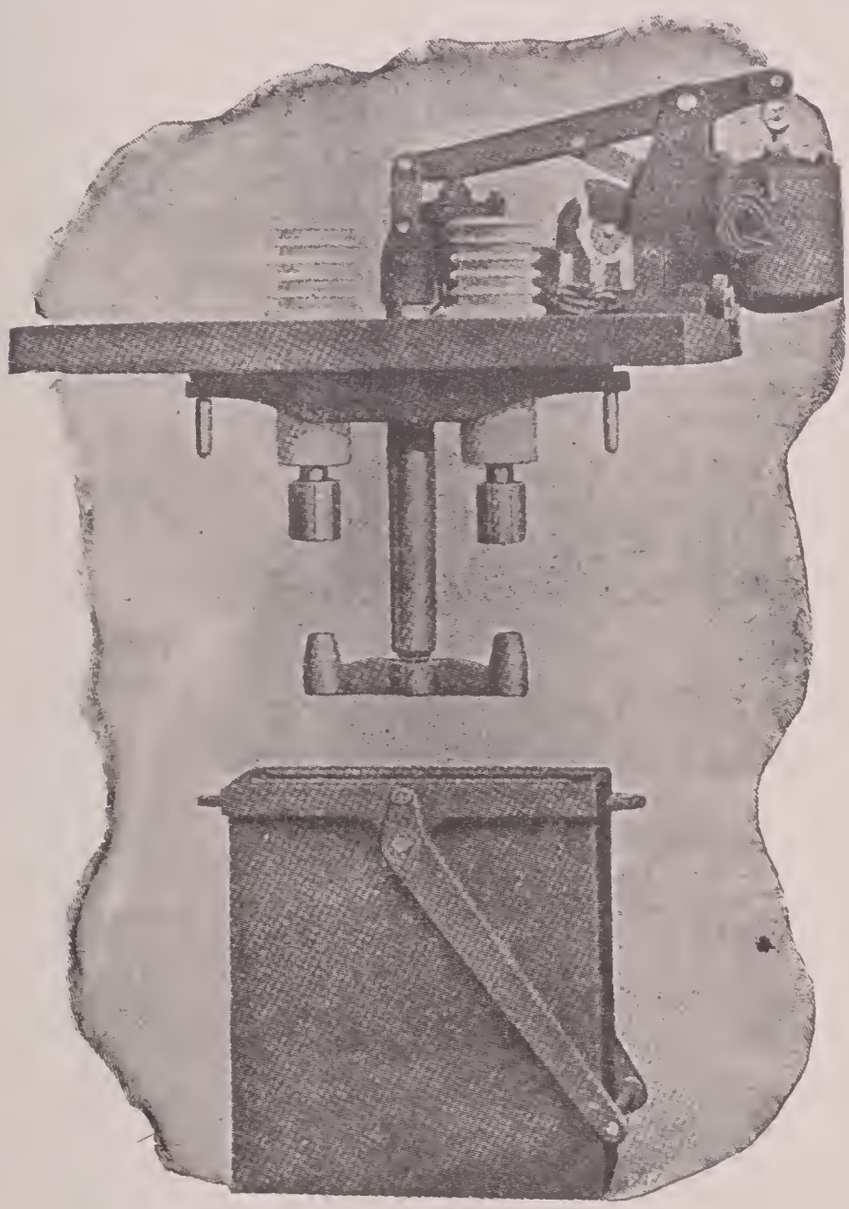


Fig. 319. Magnetically Operated Oil Switch.

The lamps with bull's eyes are controlled by an auxiliary switch attached to the operating mechanism of the oil switch. The opening of the oil switch lights up

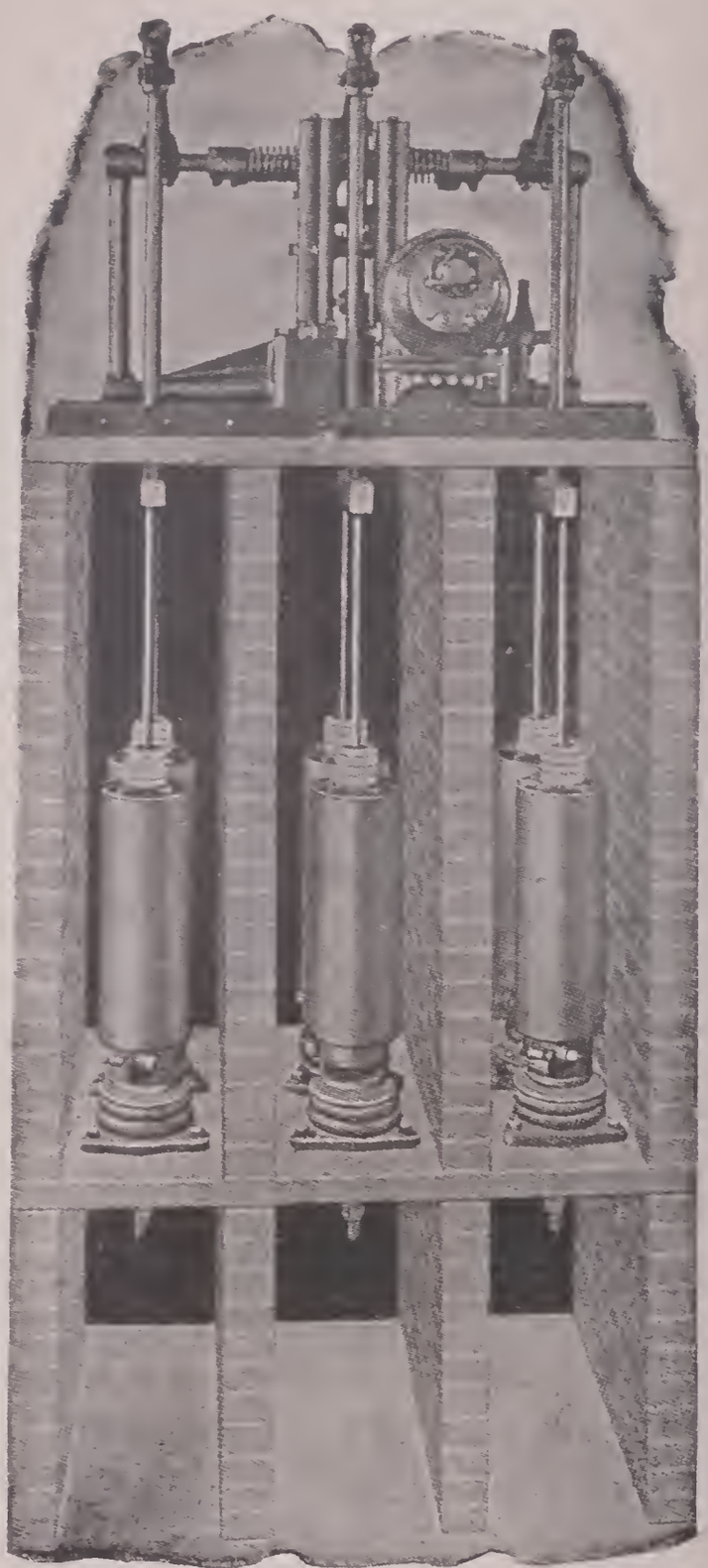


Fig. 320. Motor Driven, T. P. S. T. 13,000 Volts 300 Ampere Oil Switch in Brick Cell.

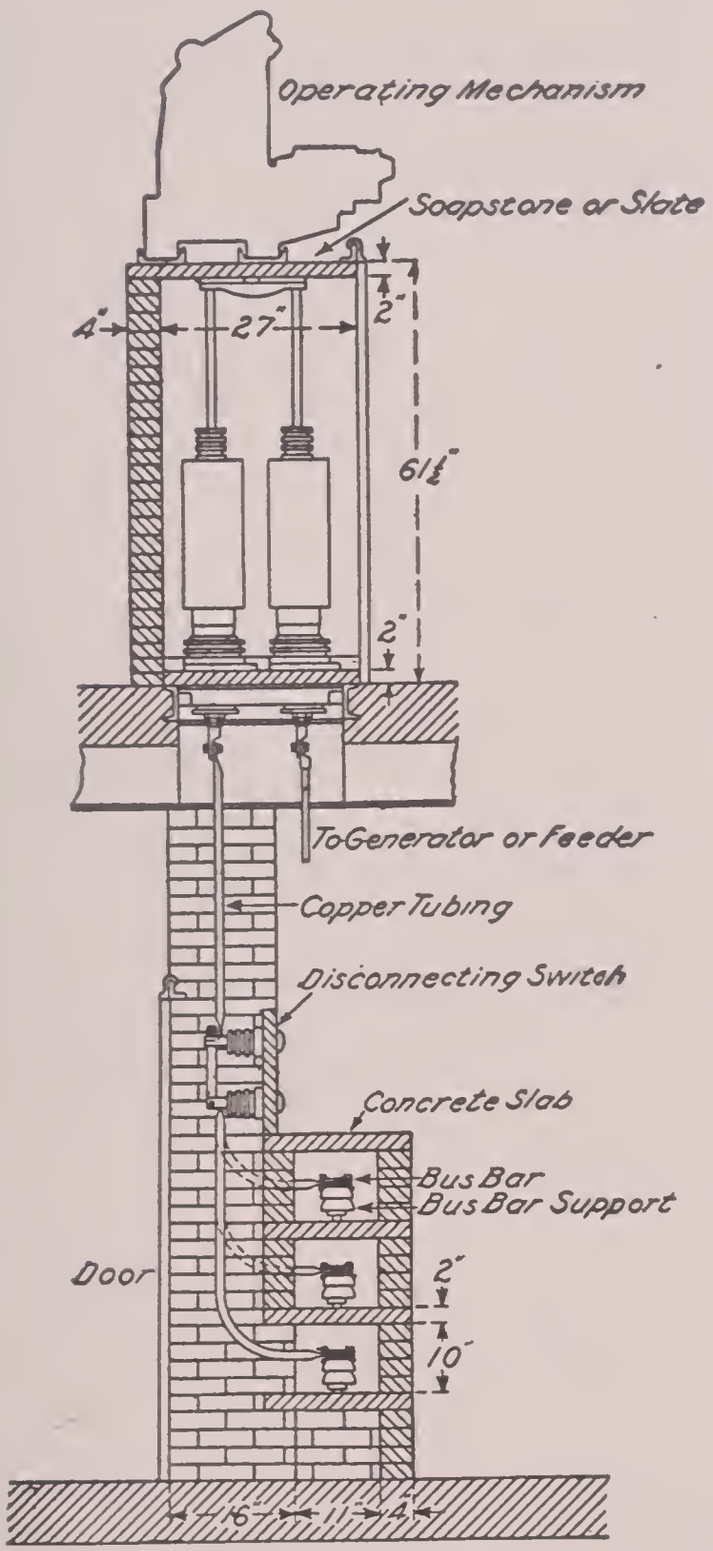


Fig 321. An Arrangement of 13,000 Volt Buses and Oil Switches. Very Little Floor Space Required.

the green bull's eye, and its closing lights up the red bull's eye, assuring the attendant that the throwing of the controlling switch has been followed by the proper operation of the oil switch.

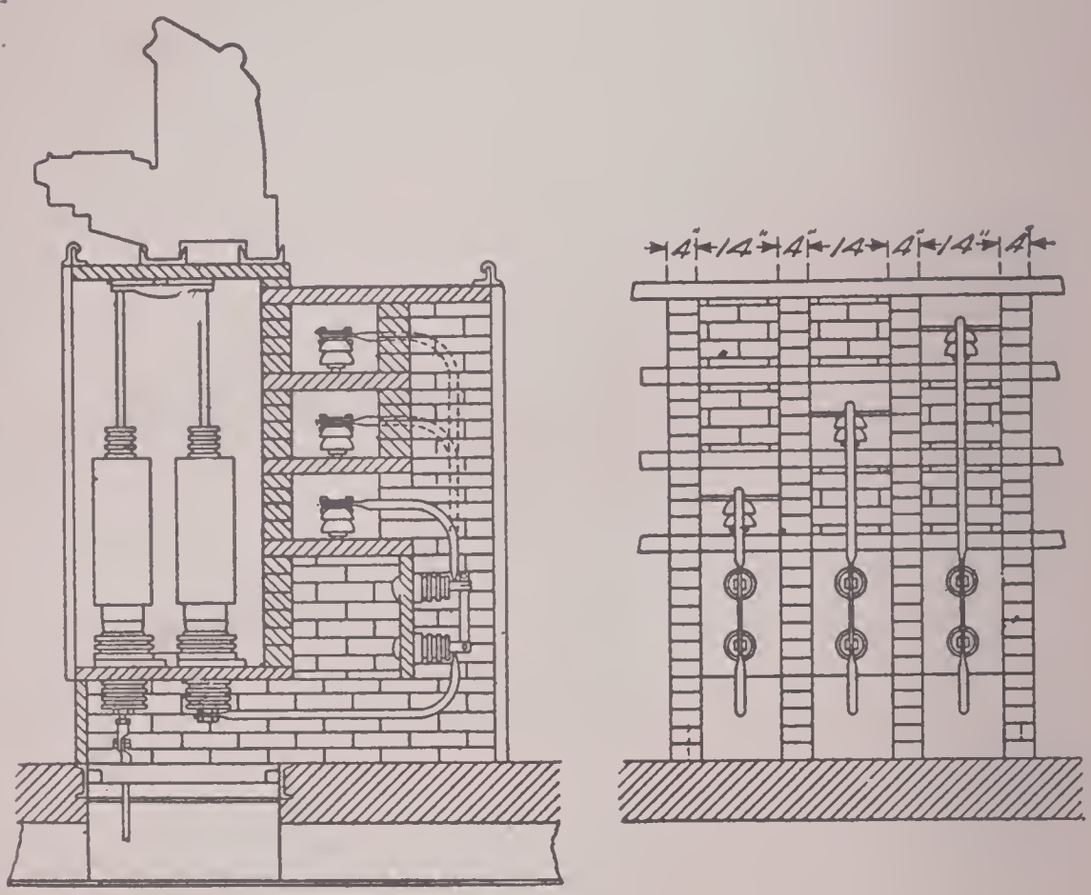


Fig. 322. A More Compact Arrangement Than Fig. 321. Needs More Floor Space.

When the current in the main circuit exceeds a predetermined value the overload relay closes a continuous current circuit, thereby tripping the oil switch.

Under some conditions, however, it is desirable to delay, for a certain length of time, the opening of the switch under its predetermined overload. To accom-

plish this result the overload relay is equipped with a time limit device.

As already stated, all high tension oil switches should be mounted in brick cells situated apart from the panels.

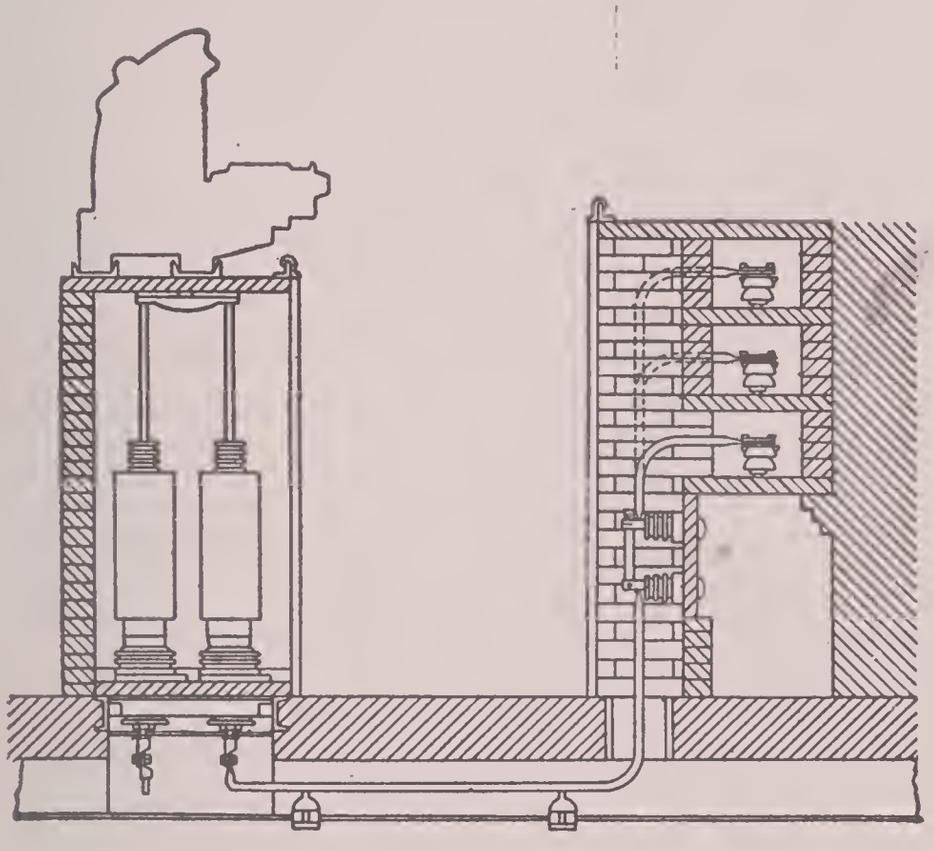


Fig. 323. Arrangement Similar to Fig. 322 When More Space is Available.

The bus-bars, disconnecting switches and oil switches need not only good insulation but separation. Fig. 321 shows one way of handling a 13,000 volt set. Fig. 322 shows side and rear view of another scheme and Fig. 323 still another way of placing them.

Field Rheostats being of such large size the arrangements shown in Fig. 324 are often necessary. In Fig. 318 the rheostat is on floor below.

Cable Connections. In order to connect large cables to the bus-bars, instrument, and machine terminals, the cables are split and the parts soldered into lugs. Fig.

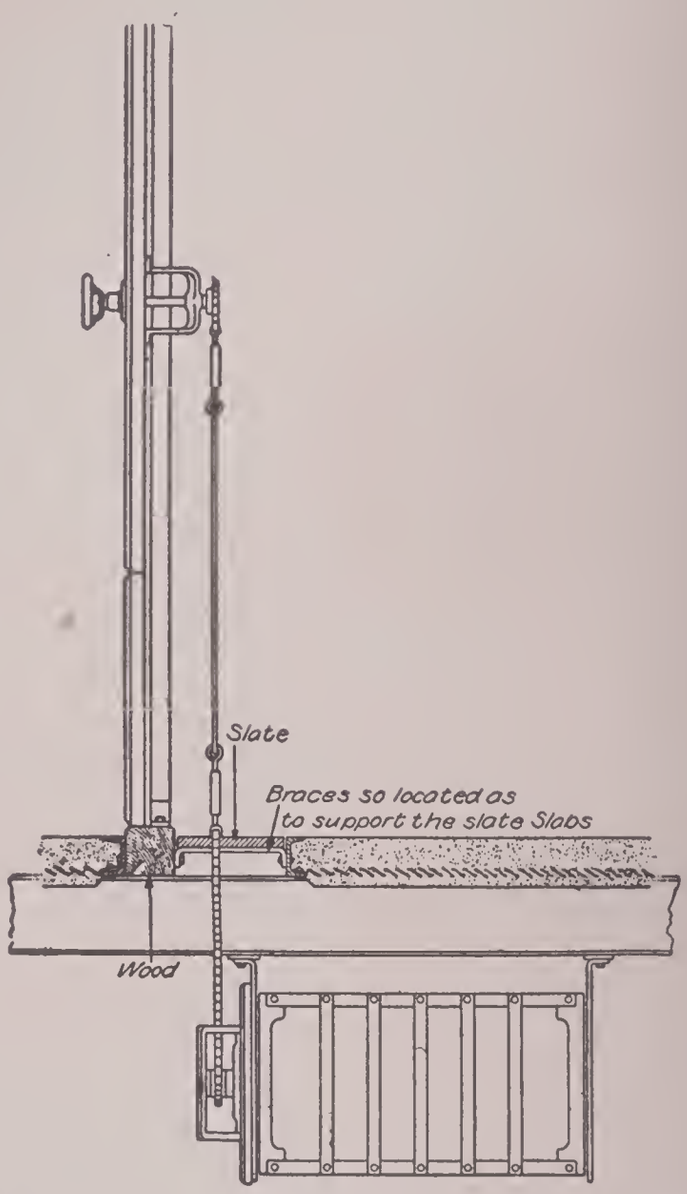


Fig. 324. Mounting and Control of Field Rheostat.

325 shows how *five* of these lugs can be placed on a stud so as to occupy as little end room as possible.

The Voltage Detector, Fig. 326, is a static device having a movable element which is set in rotation when it is

subjected to the line potential. A detector is attached to each conductor of every line, on the line side of the disconnecting switch. A complete set, therefore, consists of three detectors for each line. This device also serves as a ground detector, as its moving element will come to rest when a ground occurs on the conductor to which it is connected.

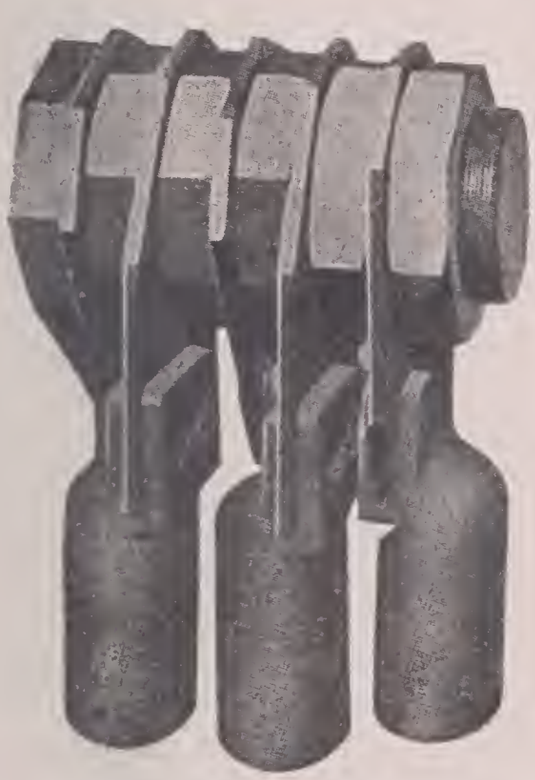


Fig. 325. Clamping a Five Terminal Cable to Panel Stud.

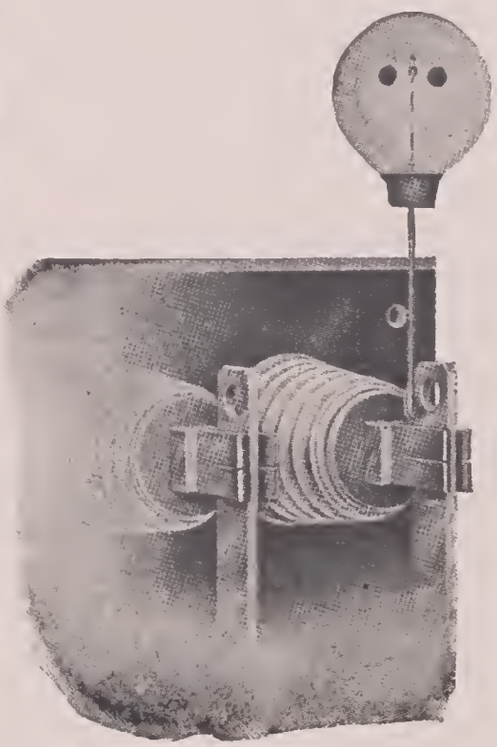


Fig. 326. Voltage Detector, for Circuits up to 15,000 Volts.

Three Single-Pole Double-Blade Disconnecting Switches (Fig. 327) are placed in each incoming and outgoing line, one switch in each conductor. One blade is used for disconnecting the lightning arrester from the line, while the other blade is used for disconnecting the station from the line. Choke coils also are recom-

mended for connection in series with the line between the arrester taps and the switchboard in order to protect the station apparatus. The arresters, switches and choke coils are designed for mounting on the wall at the point

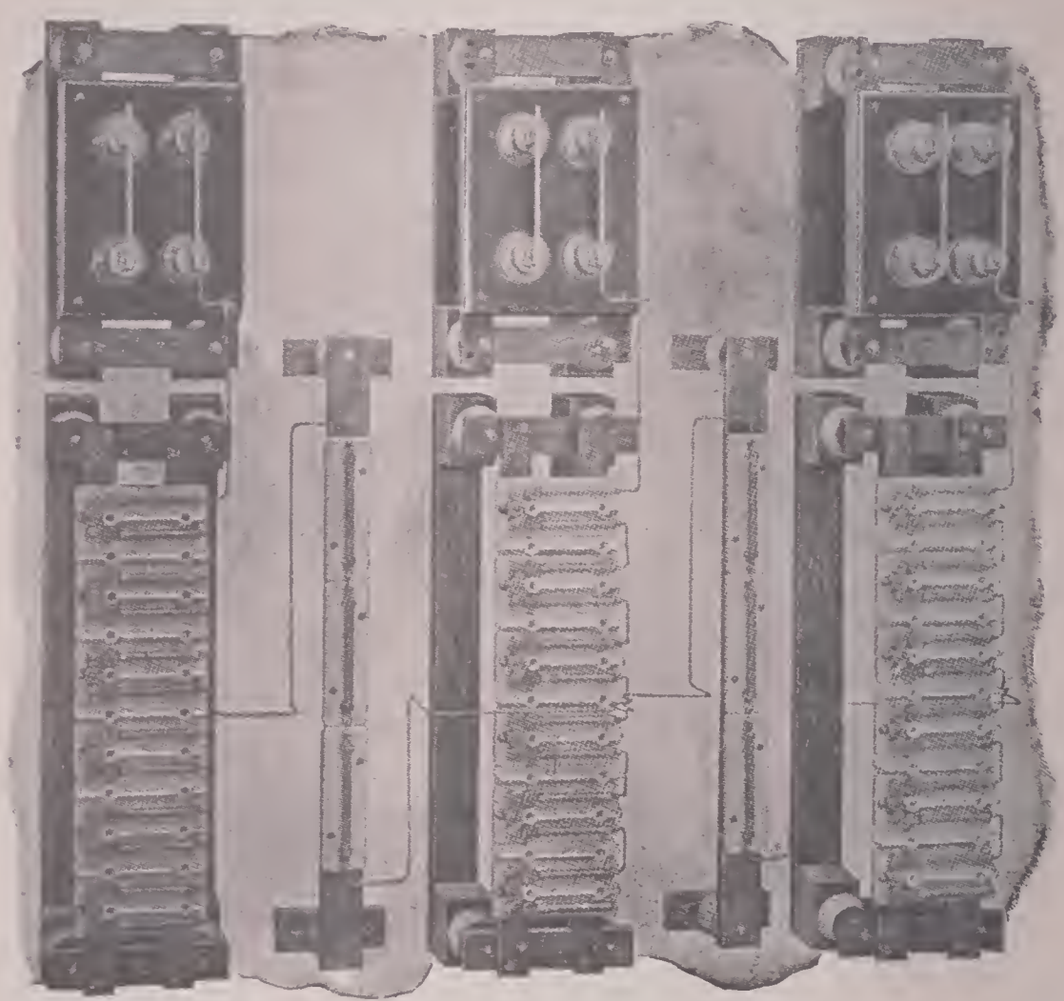


Fig. 327. 13,000 Volt, Three-Phase Lightning Arrester.

where the lines enter the station. The switches may be furnished either front or back connected, and are mounted on slate bases and provided with heavy corrugated glass insulators for the switch studs. The blades are not

provided with handles, but have holes in the ends to enable them to be operated by a hook mounted on a long wooden handle.

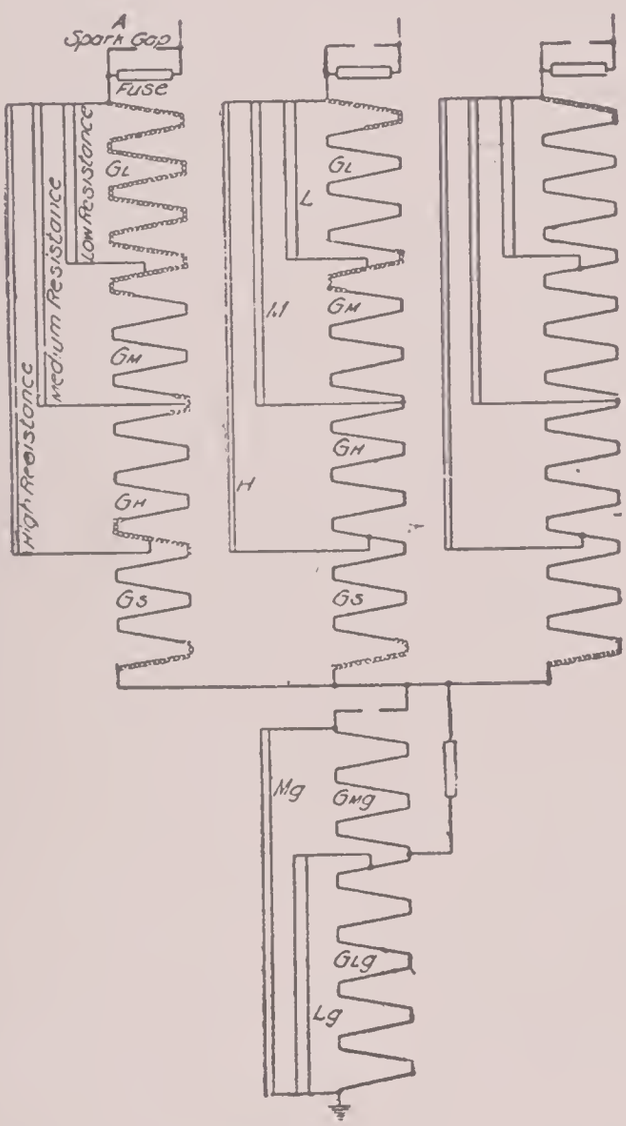


Fig. 328. Diagram of Multigap Graded Shunt Resistance, Three-Phase 33,000 Volt Arrester.

Arresters. In Fig. 327 is shown a 13,000 volt 3-phase arrester with disconnecting switches. This is the older type, but is the kind in most stations.

In Figs. 328 and 329 are given diagrams of the connections of the newer graded shunt resistance type of arrester.

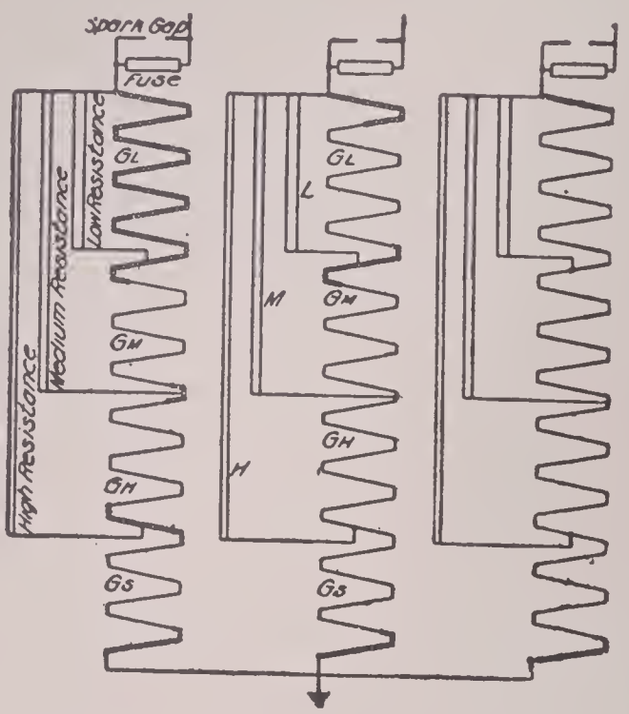


Fig. 329. Arrester Similar to Fig. 328 Arranged for Y System with Grounded Neutral.

In all these note the connections between line and line, besides the line and ground connections.

LESSON 33.

Transmission Lines, Feeders, Trolley and Third Rail.

The transmission line from power house to sub-station or point of feeding into trolley or third rail is usually a pole line.

With high voltages the use of iron poles along the right of way is becoming standard practice. Such a pole is shown in Fig. 330.

From the thickly settled parts of cities and at terminal stations the transmission line should be excluded; but the feeders must be carried underground.

This is done by running insulated cables in ducts. Fig. 331 shows cables supported on side wall of tunnel; Fig. 332 shows ducts for cables in side wall of tunnel or a station; Fig. 333 showing these same ducts arranged under platform of station.

The pole line is of bare wire, copper or aluminum, supported on porcelain or earthen ware insulators.

Fig. 334 shows a 50,000 volt insulator of three separate pieces of porcelain cemented together. It is 11 inches high and weighs 27 pounds. The distance the voltage would have to jump to get to pin or cross arm is 8½ inches.

A 60,000 volt porcelain insulator of four pieces is shown in Fig. 335, while Fig. 336 shows a 75,000 volt three piece porcelain insulator, 15 inches high, weight 40 pounds, with a sparking distance of 11 inches.

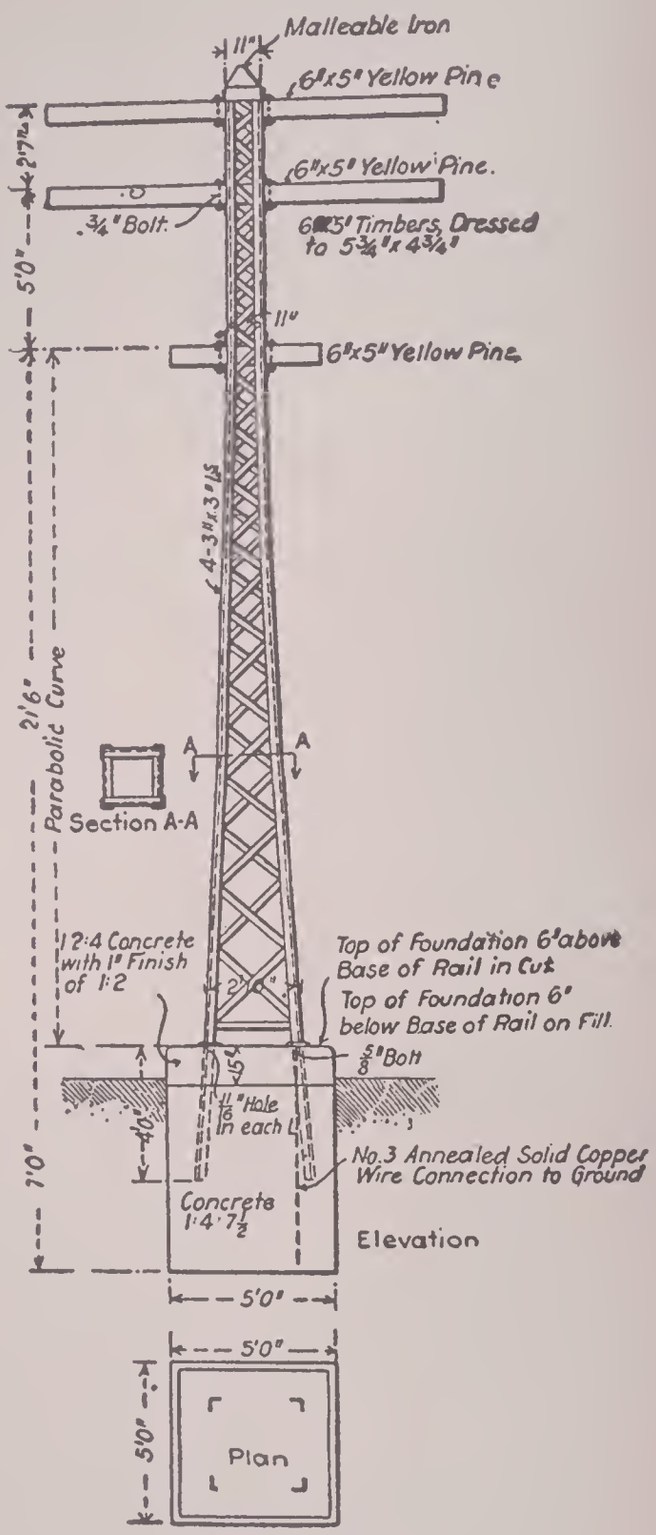


Fig. 330. Transmission Line Pole. New York Central R. R.

When cables are used the voltage is usually lower and glass may be used. Fig. 337 is a glass insulator for cables carrying a pressure of not over 10,000 volts.

Iron pins are used now, as shown in Fig. 338, because the distance the arc must jump is increased by use of a porcelain covered iron pin. Fig. 339 shows the sparking distance with wood pin, and Fig. 340 the increase with porcelain covered iron pin.

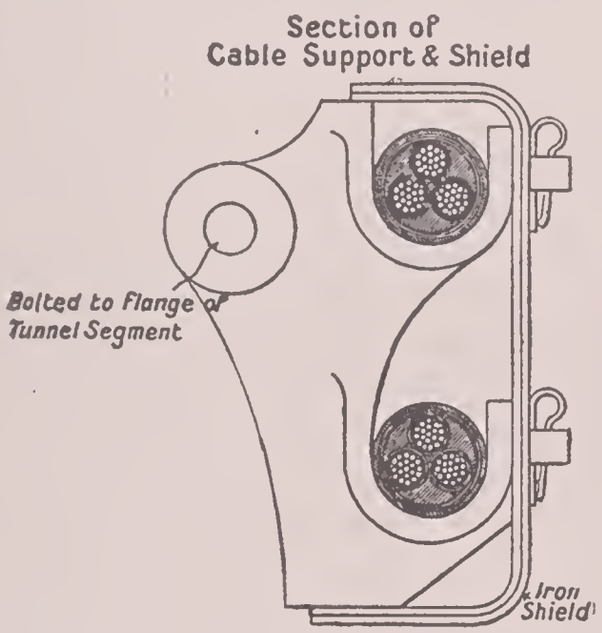


Fig. 331. Cables Supported on Side of Tunnel.

Fig. 341 shows a pin ready to be put straddle of a pole top and Fig. 342 shows an iron pin adapted to bolt on the side of the pole. The porcelain cover has not yet been attached to this pin.

The sparking or arcing distance on an insulator is estimated by imagining a rain storm coming at an angle of 45° and thus conducting the electricity from top umbrella or petticoat to the pin sleeve as in A, Fig. 343.

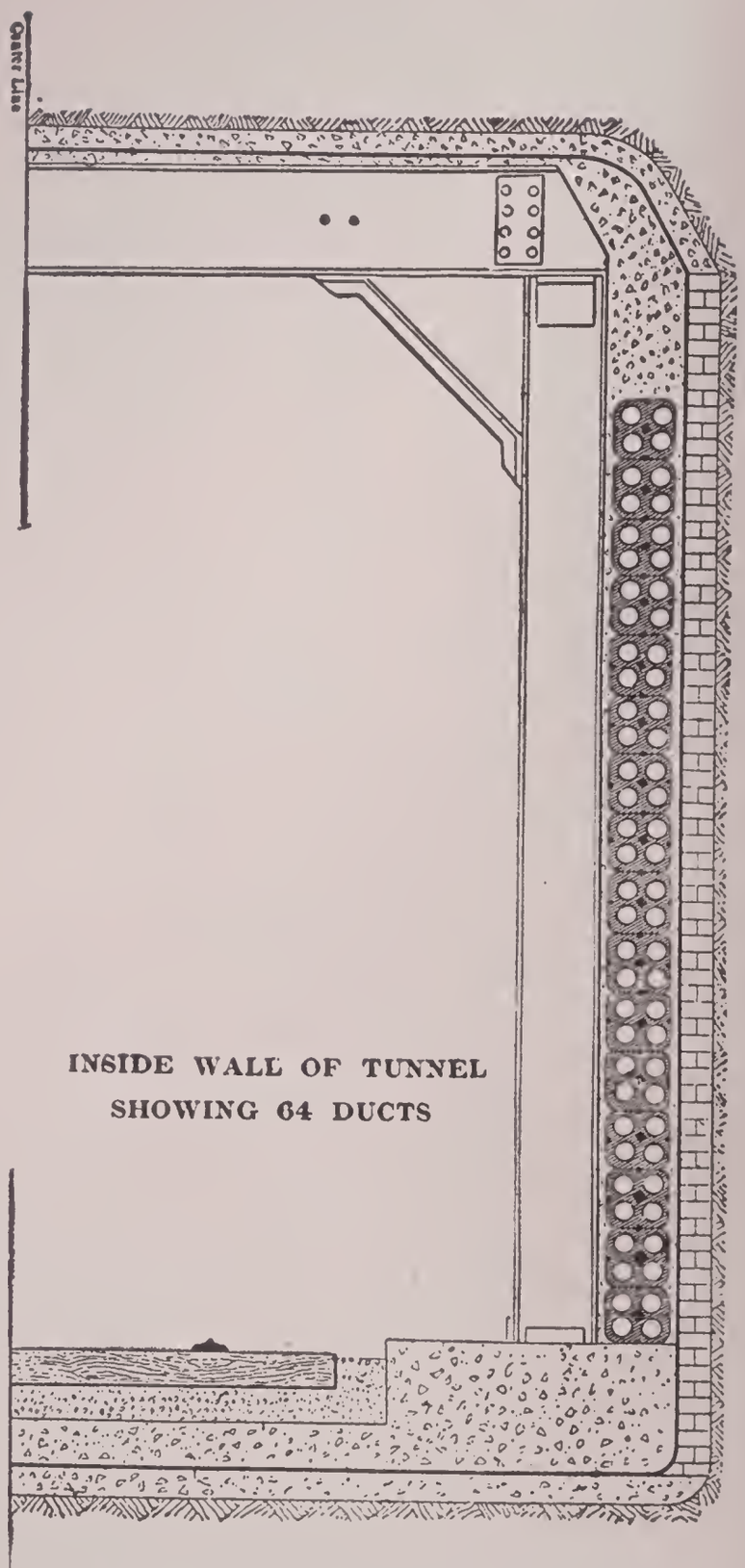


Fig. 332. Ducts Inside of Wall of Tunnel.

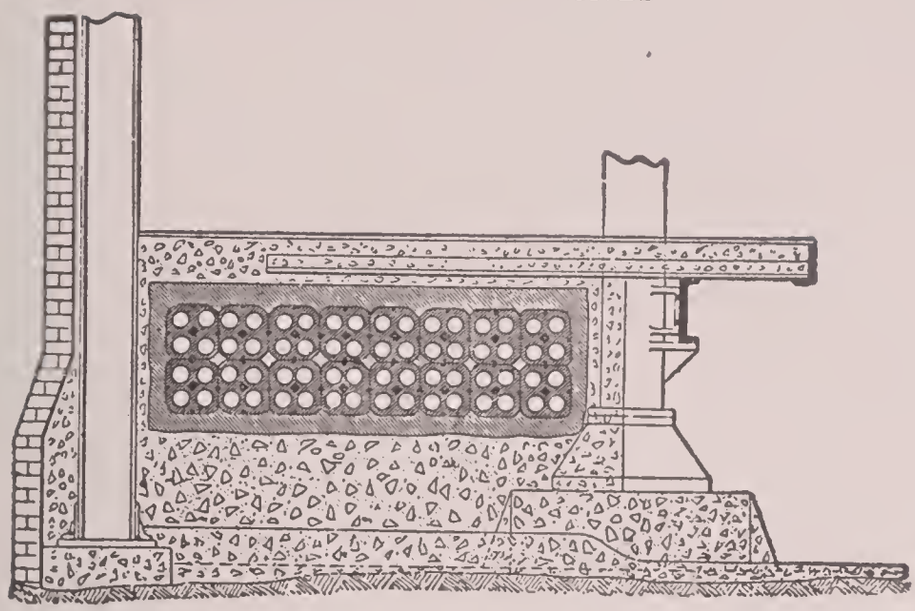


Fig. 333. Ducts Under Passenger Station Platform.

Fig. 334. 50,000 Volt Insulator.

This distance plus the distance B across which the spark would have to jump gives total sparking distance.

When the high tension wires enter a sub-station the arrangement of Fig. 344 is a good one. A large square of slate holds a tube of porcelain, while the shed keeps

Fig. 335. 60,000 Volt Insulator.

whole dry. A sectional view of the porcelain tube is given in Fig. 345.

When the line drops from pole to sub-station a set of strain insulators must be put in to hold the end of line taut. Fig. 346 shows a complete one for moderate pres-

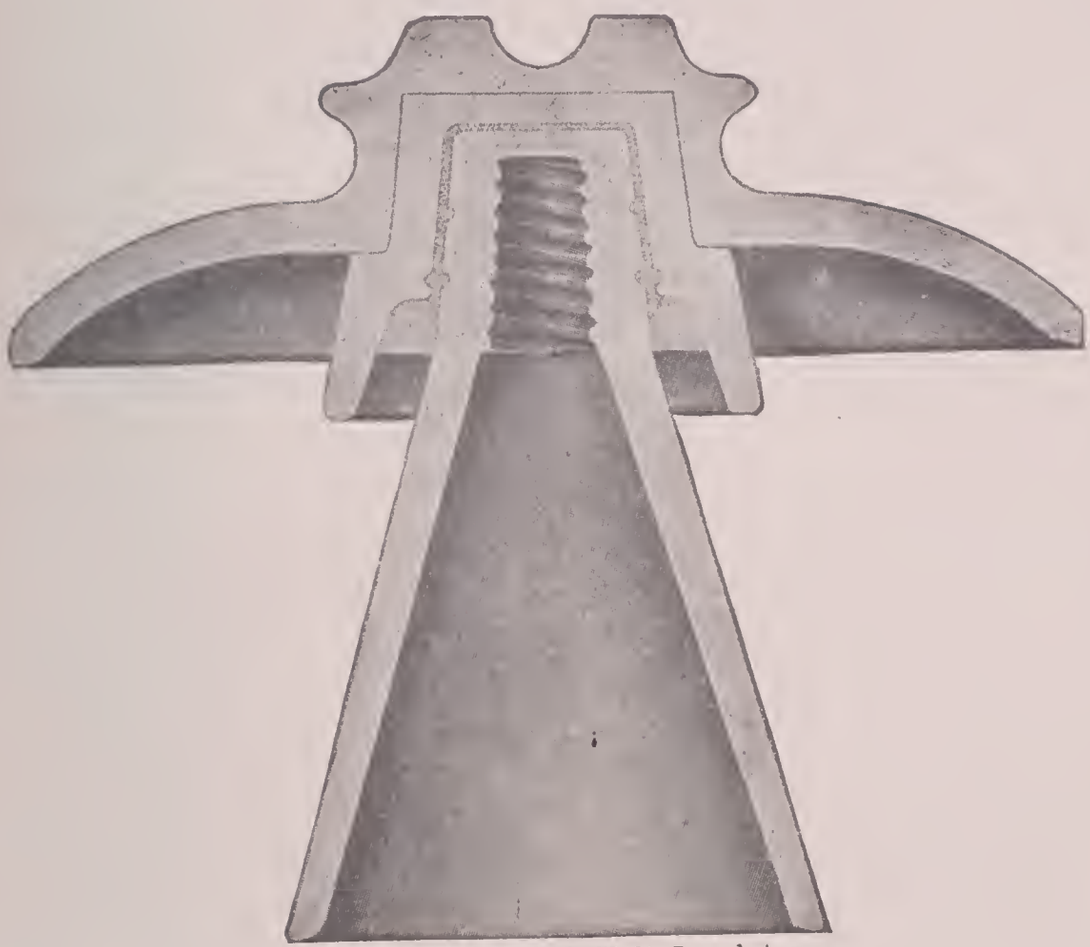


Fig. 336. 75,000 Volt Insulator.

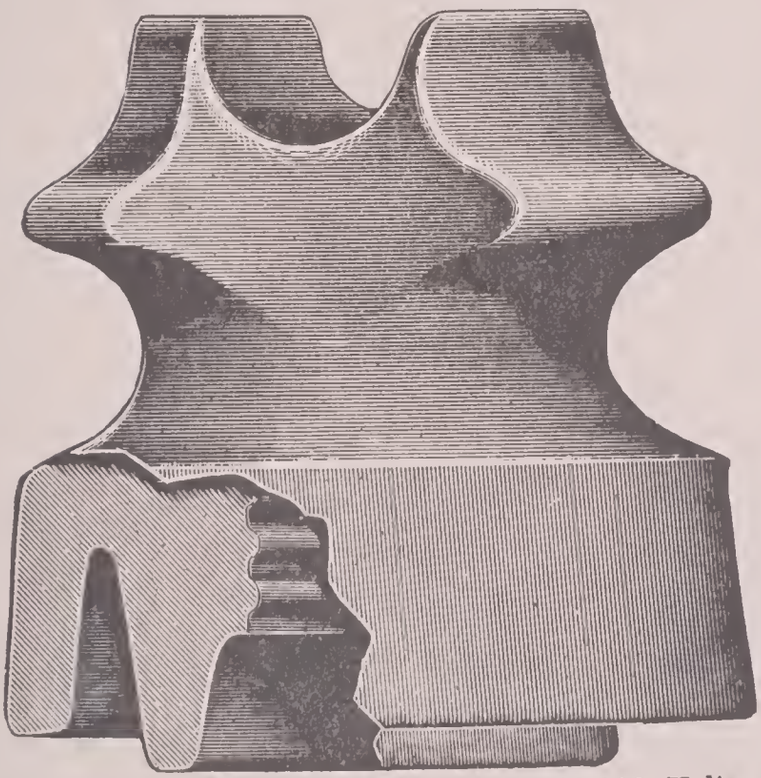


Fig. 337. Glass Cable Insulator, 10,000 Volts.

sures and one end of a triple one when the line is very heavy.

The testing of insulators is shown in Fig. 347, but in addition to this insulators are also tested when complete in their natural position, with regular voltage, while a stream of water, at a downward angle of 45°, is being played on them from a hose.

Fig. 338. Iron Pin for Cross Arm.

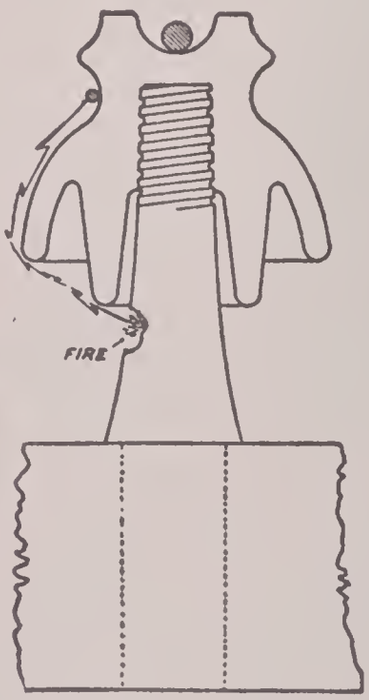


Fig. 339. Arcing When Wood Pin is Used.

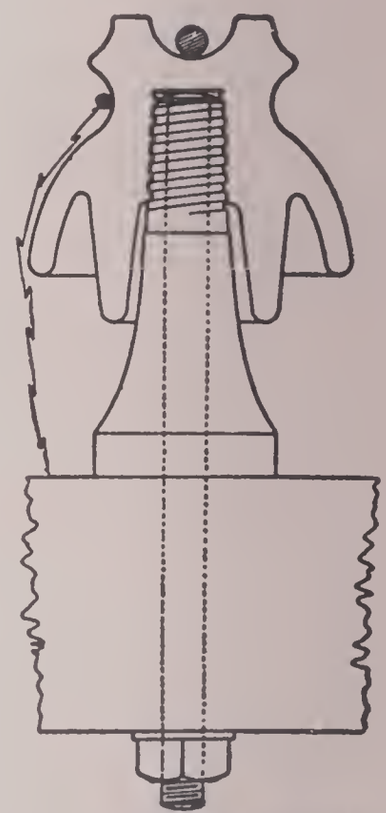


Fig. 340. Sparking Distance When Porcelain Covered Iron Pin is Used.

Overhead Trolley Line.

The old-fashioned single trolley wire with trolley wheel collecting current is unsuitable for high speeds. Its place is taken by the catenary line and bow trolley.

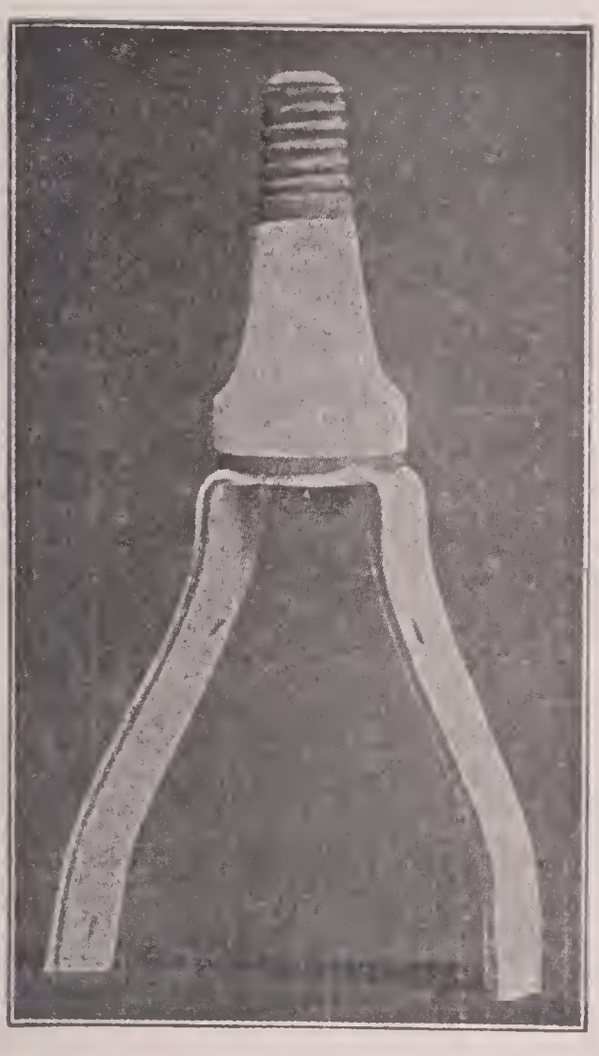
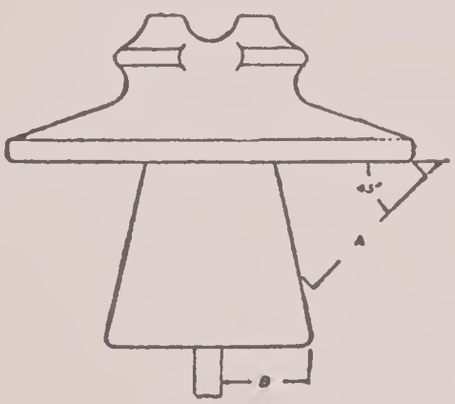


Fig. 341. Pin for Top of Pole.

Fig. 342. Pin for Side of Top of Pole.



$A + B = 4\frac{1}{2}'' =$ Arcing Distance Wet

Fig. 343. Measurement of Arcing or Sparking Distance.

Figs 348 and 349 will best explain the catenary trolley. Two steel cables are slung between the cross bridges and hang in a natural curve. They are six feet apart at the

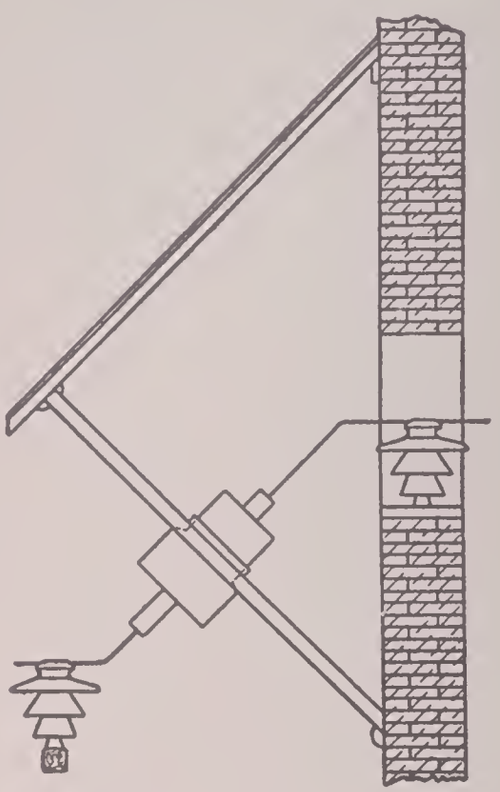


Fig. 344. Bringing In or Taking Out High Tension Line.

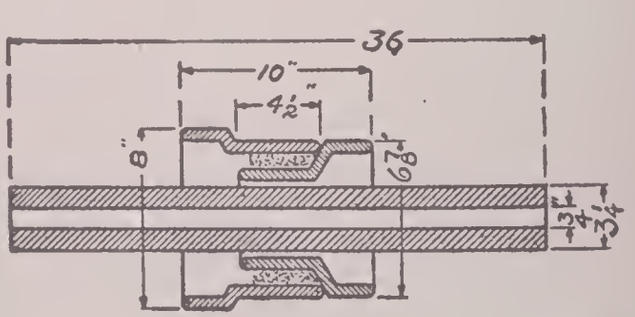


Fig. 345. Sleeve of Fig. 344, also used for Transformer Leads.

ends of the span and six feet lower in center than at ends. A number of triangles of light rods are made up of different sizes. The largest being 6 feet on each side and smallest 1 foot on each side.

These triangles are fastened to the two steel cables at their corners. This brings the cables in near each other at centers of spans. They therefore, starting from the cross bridges or gantries curve in and down.

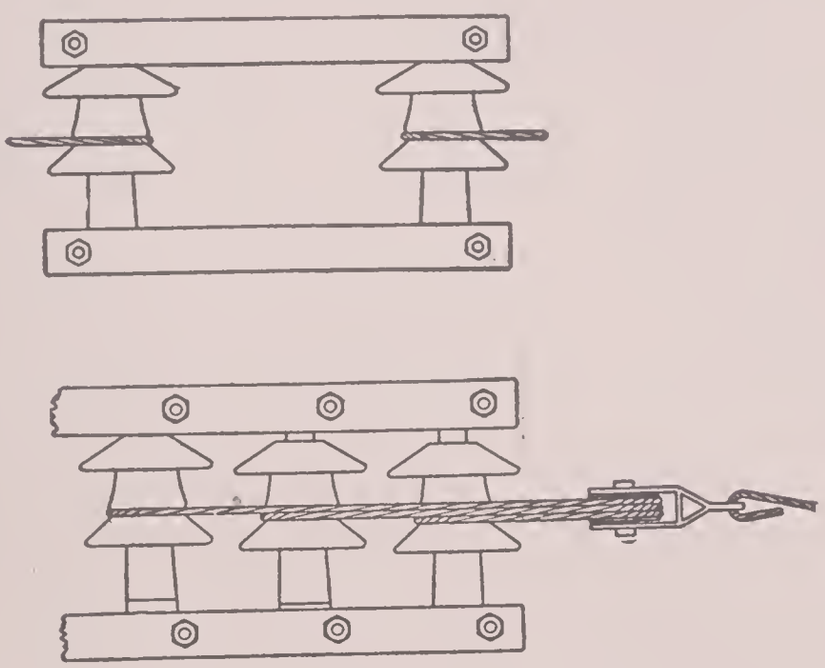


Fig. 346. Single Pin Strain Insulator and one end of a Triple Pin Strain Insulator.

The other corners of the triangles all fall in a straight line 22 feet above the level of track. The copper trolley wire is soldered into the ears which the lower corners of triangles carry.

Fig. 349 shows the curve of the supporting catenary construction and the straight line of the trolley wire.

Fig. 350 shows a gantry with section switches and transformers for operating switches and lights. These gantries occur every two miles. Fig. 351 gives a diagram of such a gantry, also carrying signals. Fig. 352 gives a diagram of a whole span showing curving of cables.

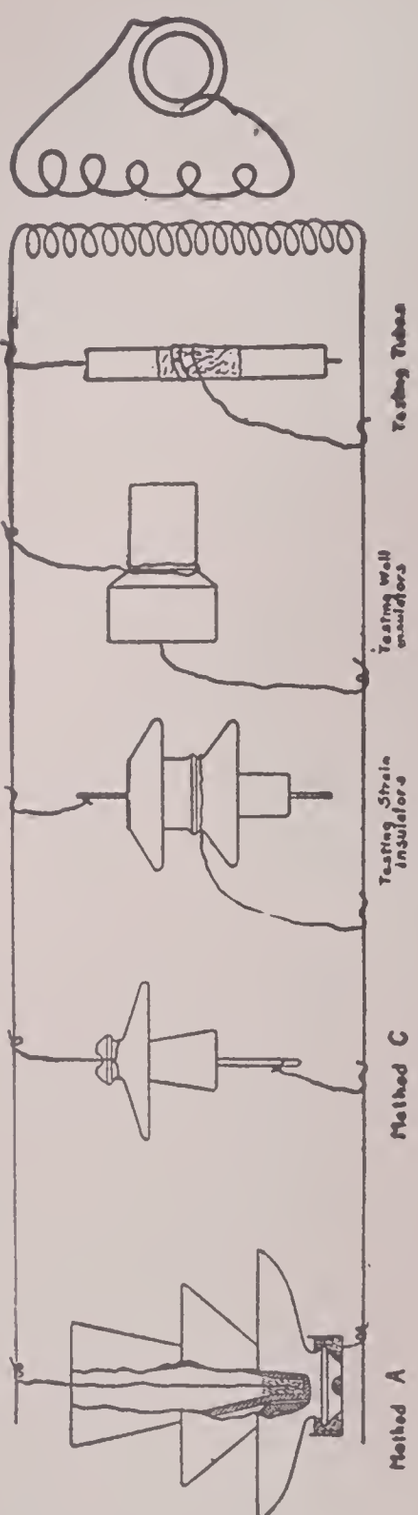


Fig. 347. Method of Testing Insulators.

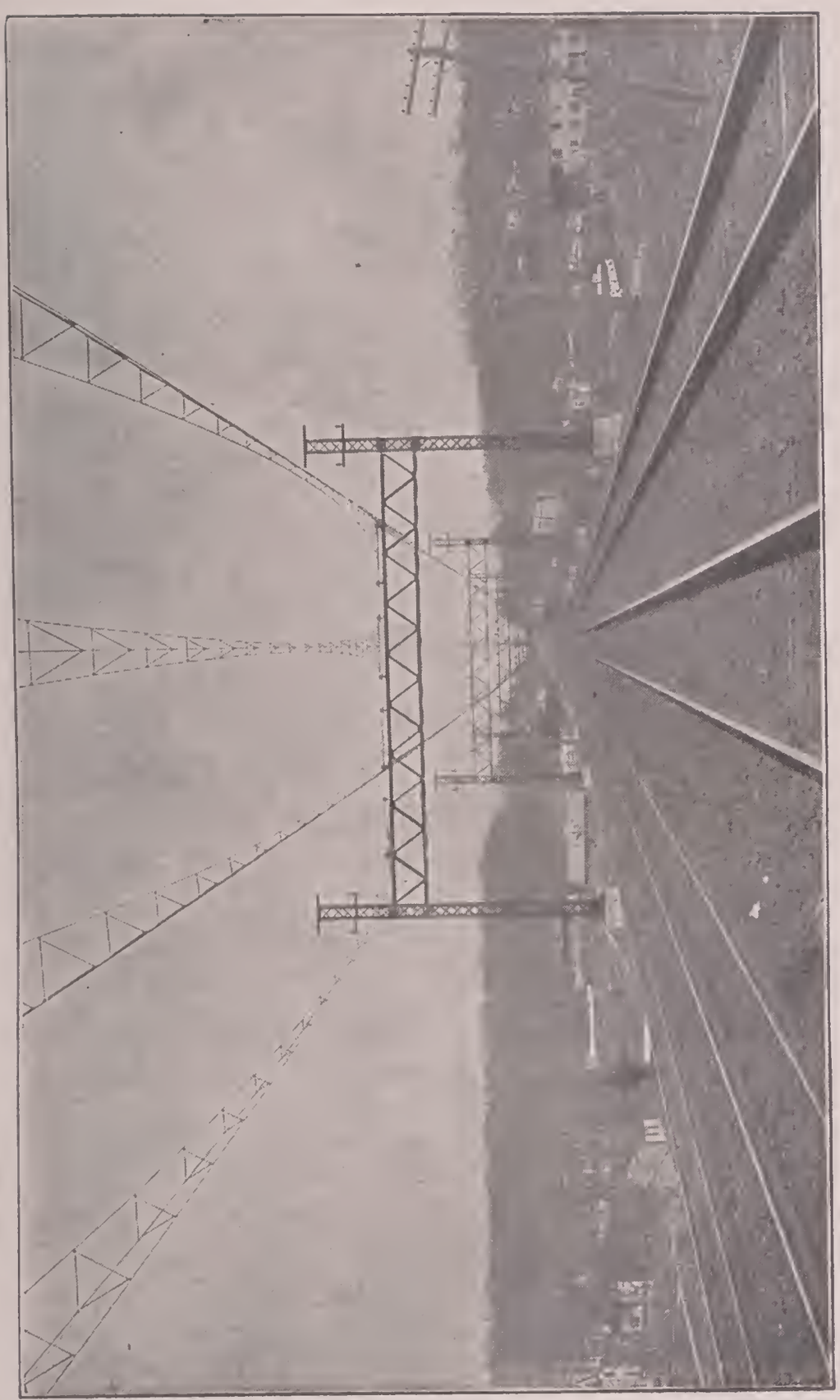


Fig. 348. Four Track Catenary Line, N. Y. N. H. & H. R. R.

Fig. 349. Catenary Line.

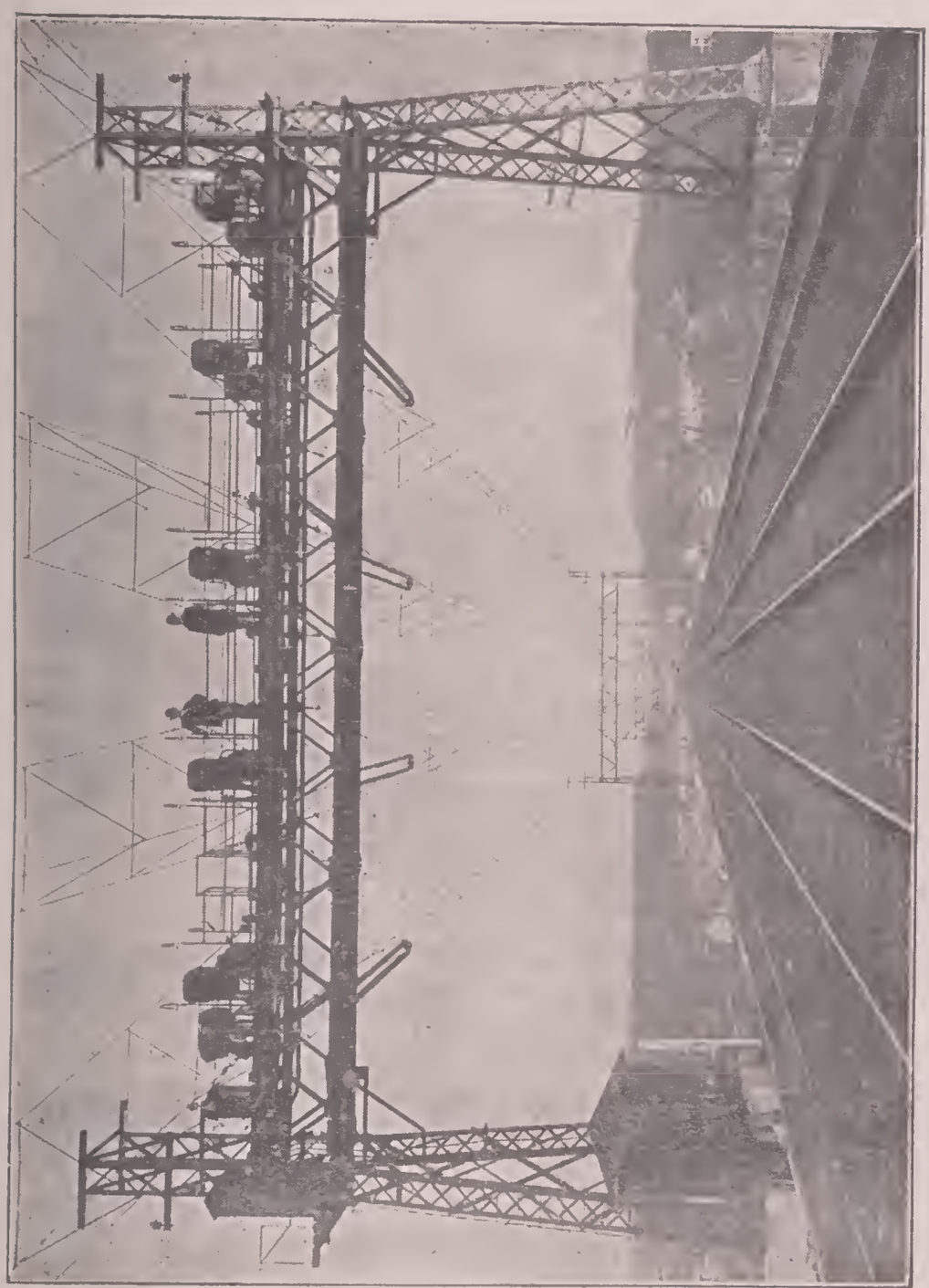


Fig. 350. Gantry with Section Switches, N. Y. N. H. & H. R. R.

Third Rail.

The third rail is usually a 70 pound ordinary steel rail, but lately rails with a certain percentage of copper in them are being used. The rail of the New York Central is copper alloyed.

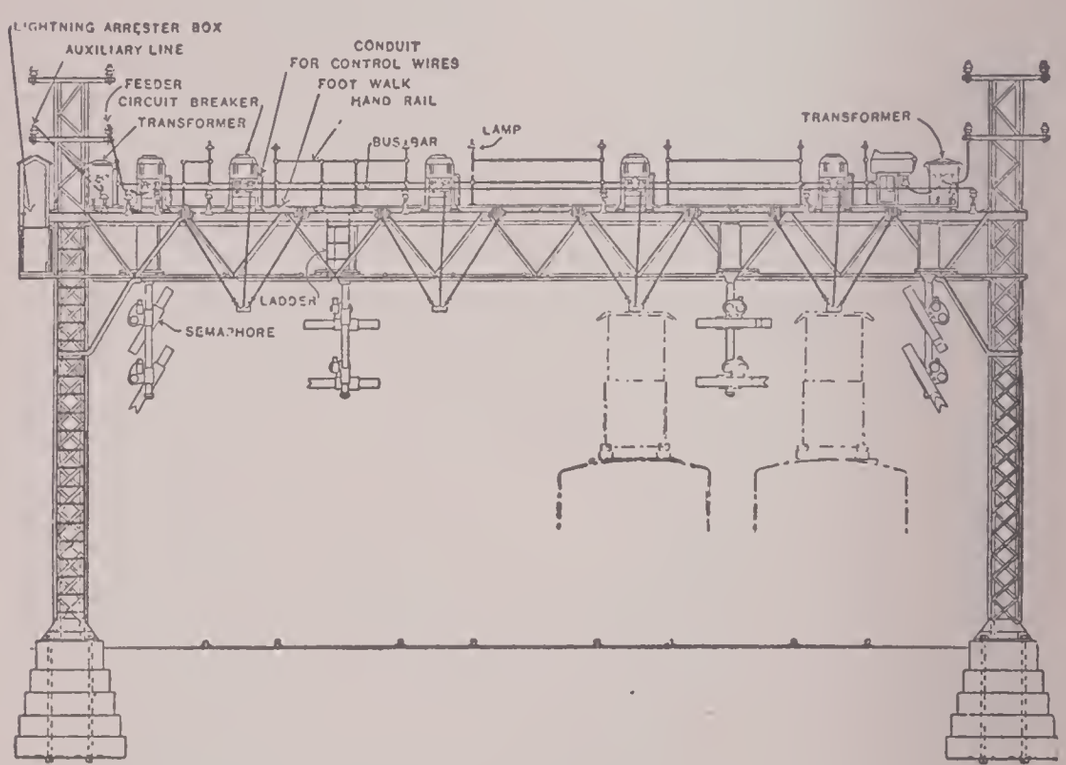


Fig. 351. Gantry with Full Equipment Showing Clearance of Two Locomotives with Trolleys Raised.

Some of the methods of installing the third rail are shown in Fig. 353, while Fig. 354 shows the New York Central under contact type. Heavy snow and sleet storms have shown the under contact to be the most reliable under such conditions.

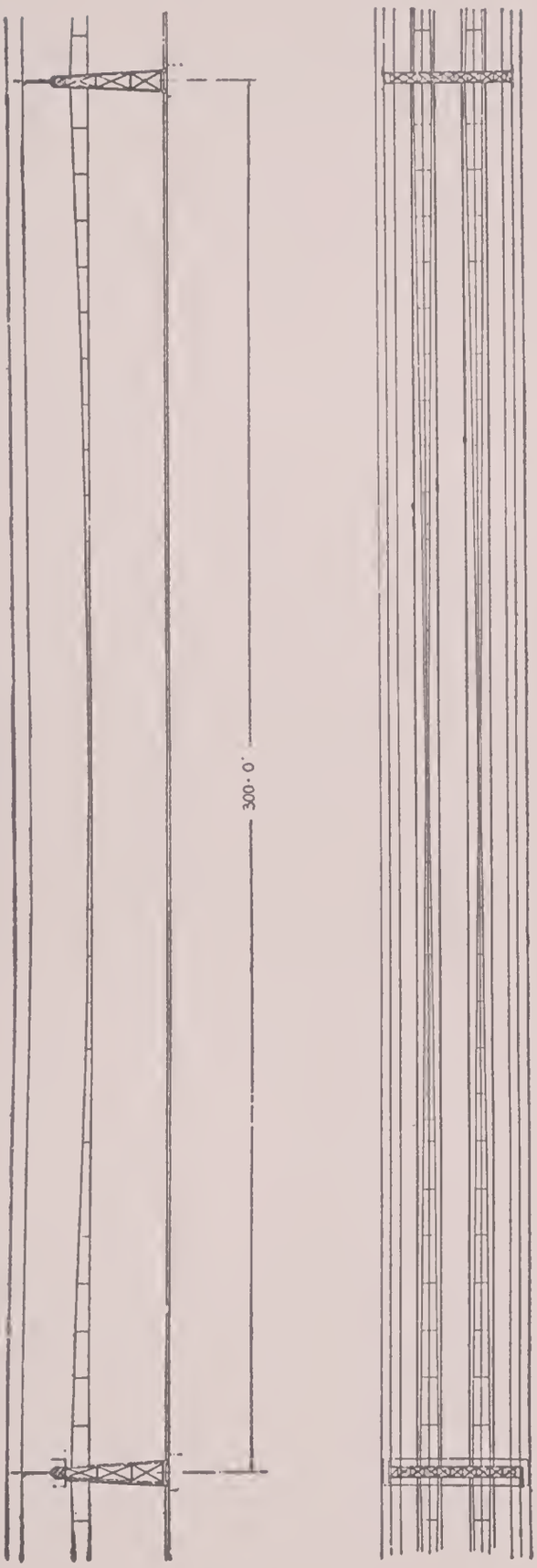


Fig. 352. Side View and Plan of Catenary Span.

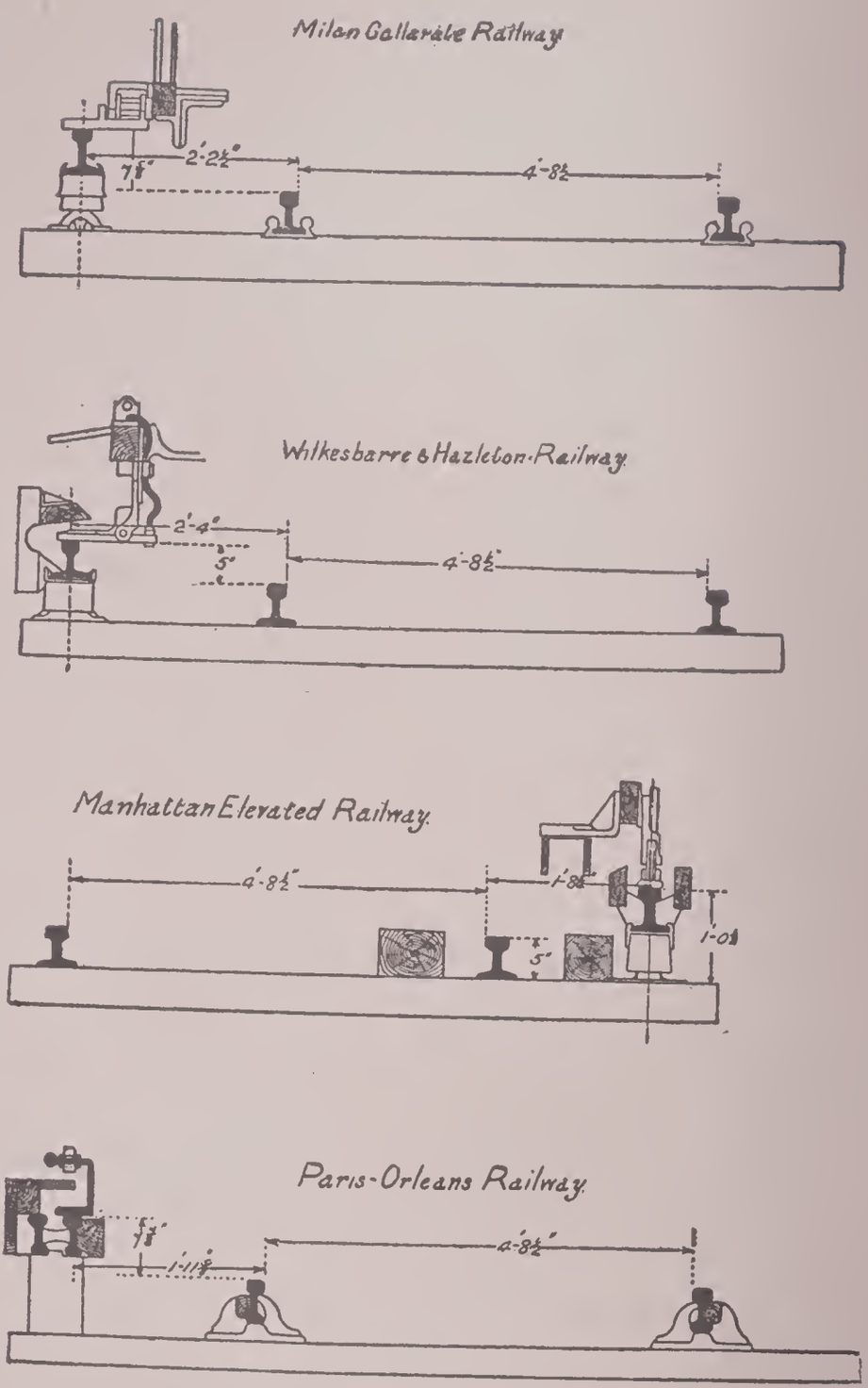


Fig. 353. Third Rail Constructions.

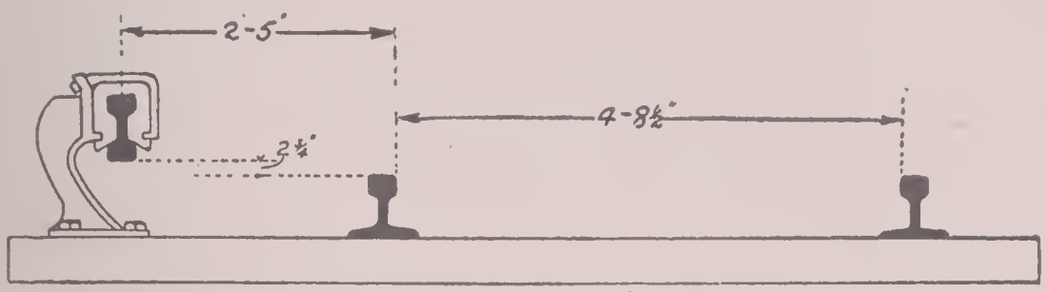


Fig. 354. New York Central Third Rail Construction.

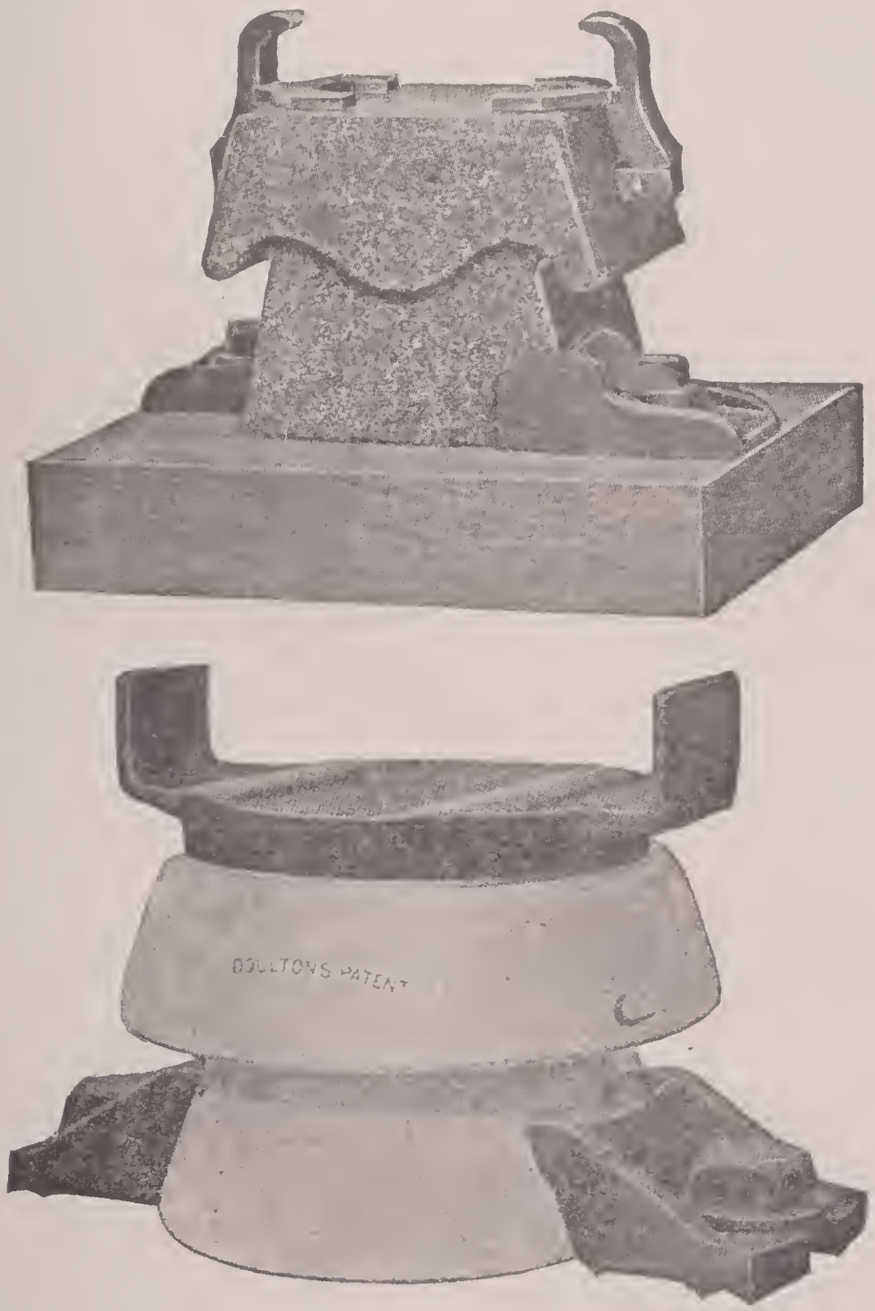


Fig. 355. Third Rail Insulators.

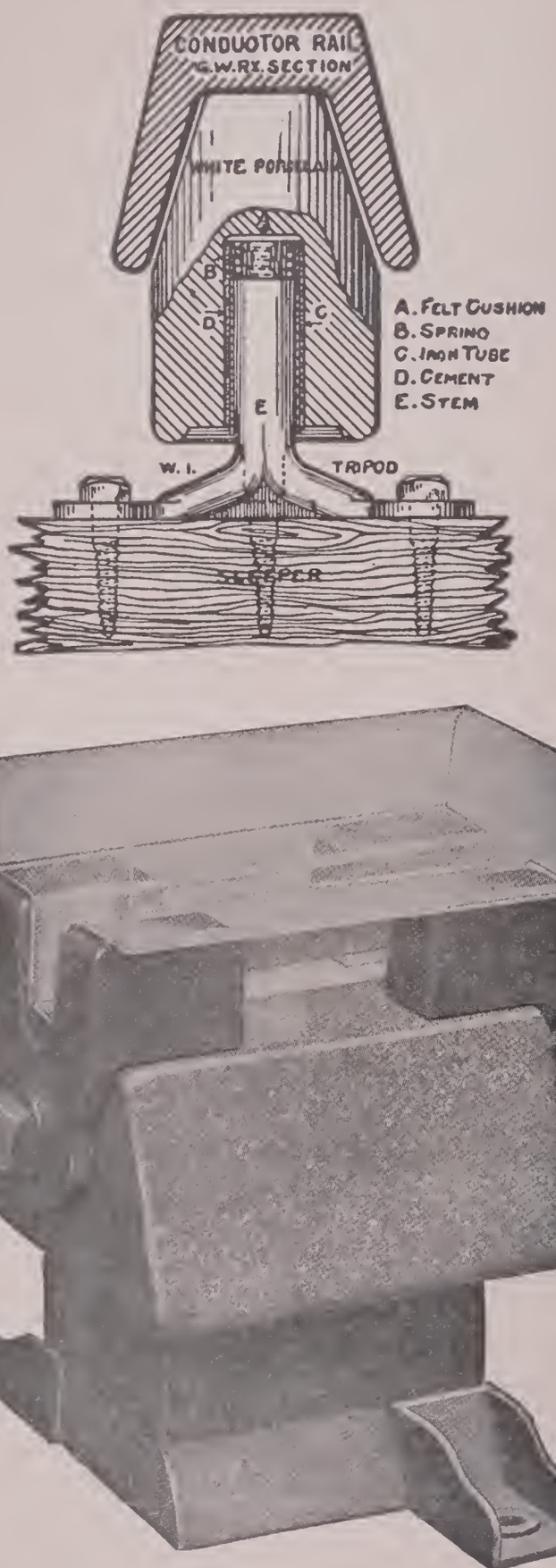


Fig. 356. Two English Third Rails and Insulators.

Insulators for third rail are made of earthen ware and stones such as soap stone. Figs. 355 and 356 show such insulators.

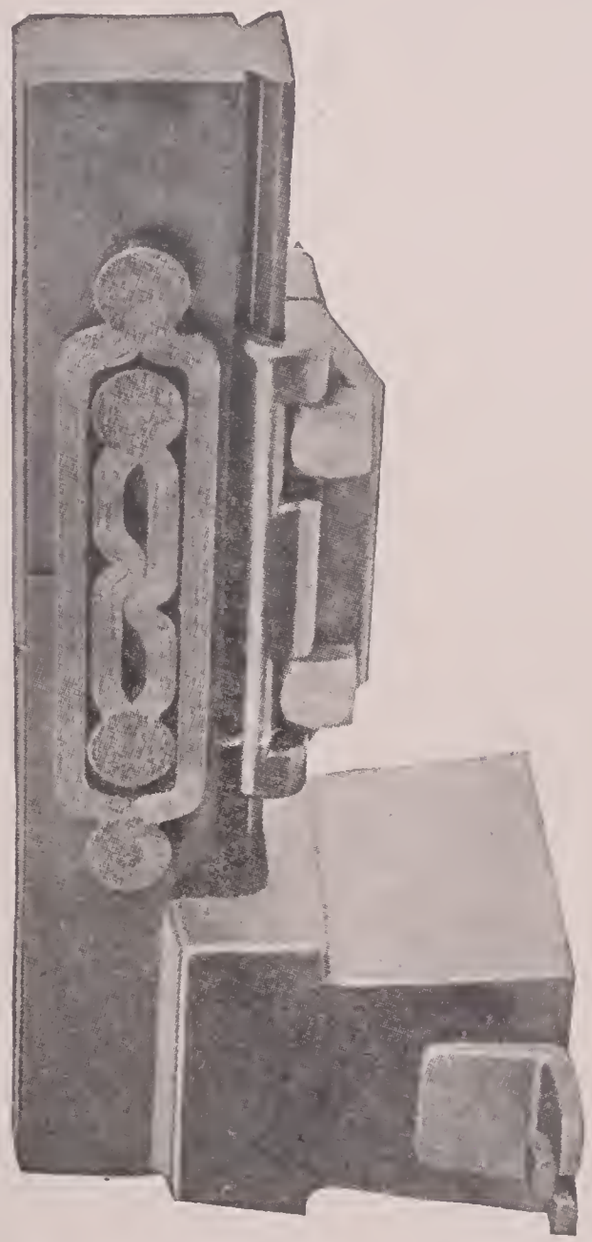


Fig. 357. Third Rail, Insulator, Connector and Riveted Bond.

Bonding.

The resistance of the joints in the third rail or track rails (which return current to power house) is so great that they are shunted by copper conductors called bonds.

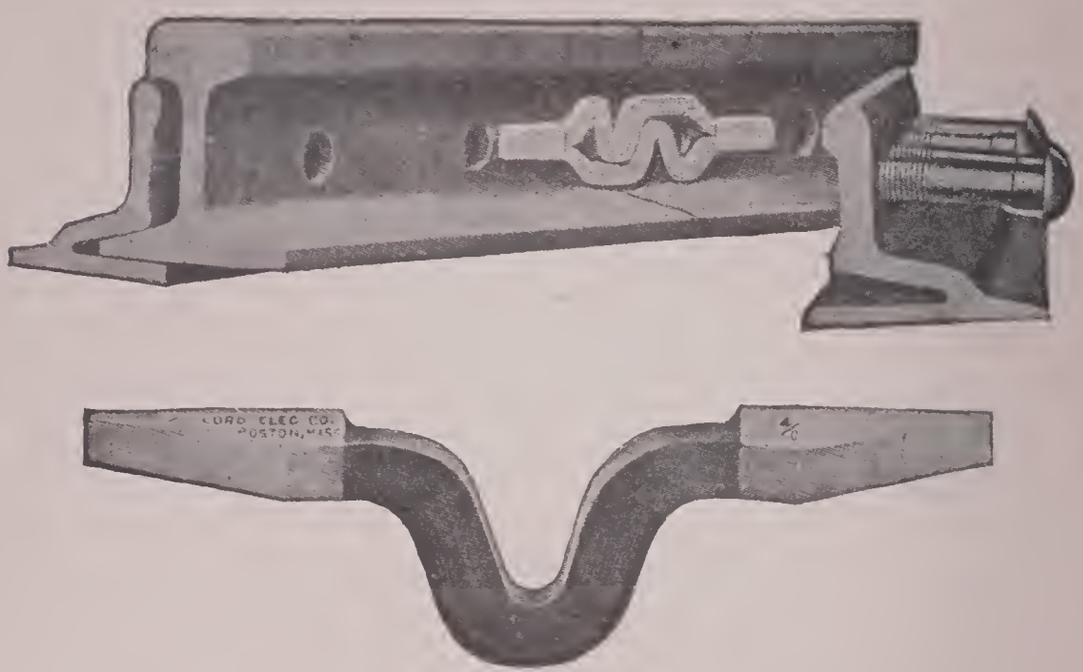


Fig. 358. Bond Protected by Fish-Plate. Soldered to Rail.

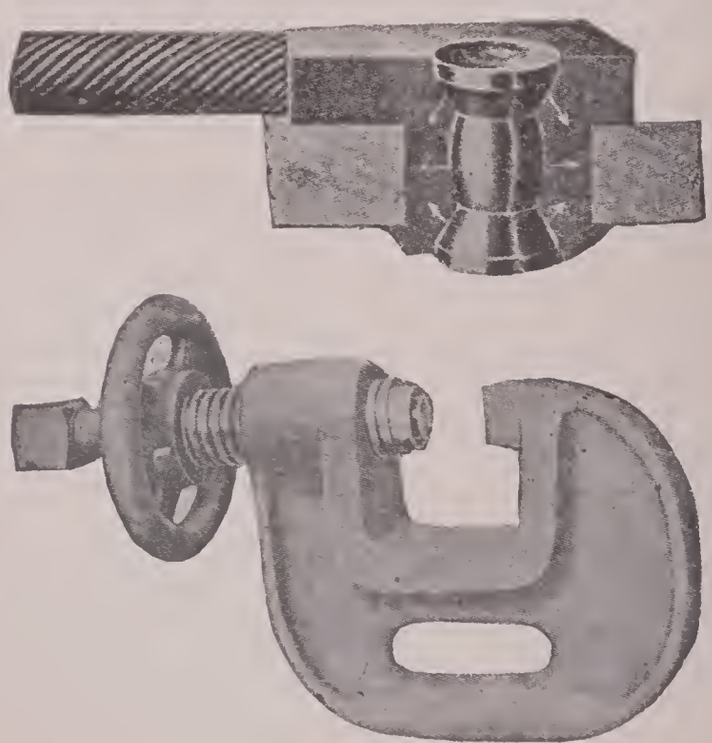


Fig. 359. Riveted Bond and Screw Compressor.

Fig. 357 shows a bond whose conductivity is as good as that of the rail itself.

To prevent theft of bonds, for the value of the copper, they are generally installed under the fish plates as in Fig. 358. They may be soldered on rail as in this case or may be inserted in drilled holes and riveted in by screw press. Fig. 359 shows the riveted end and the screw press.

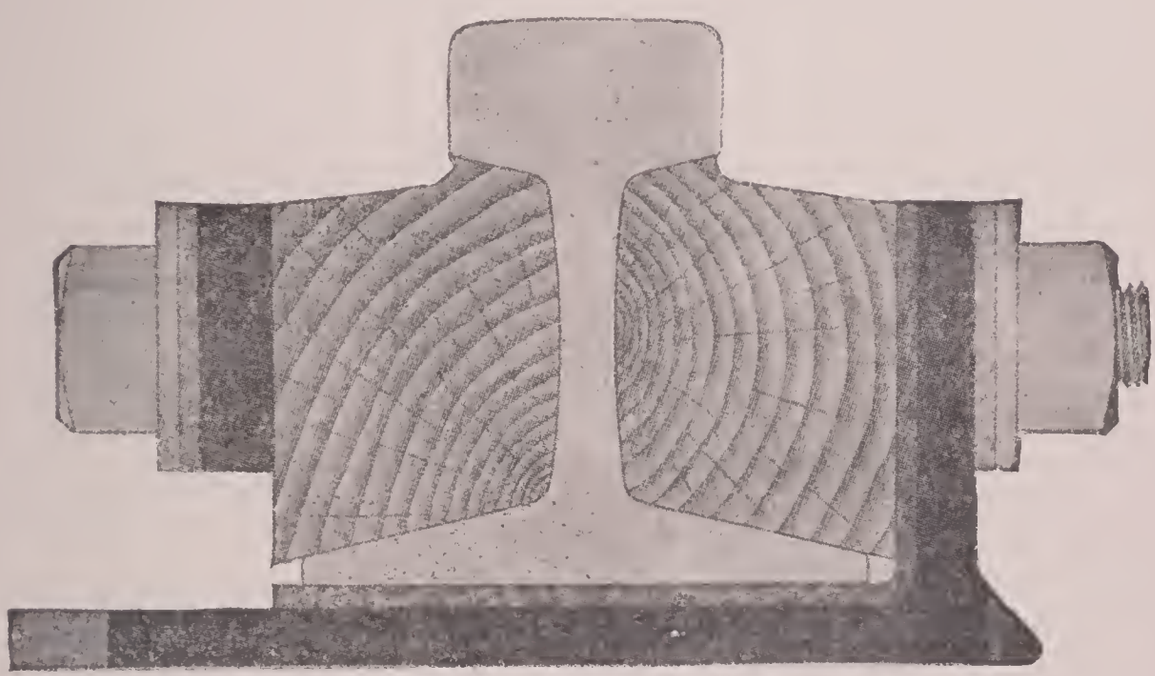


Fig. 360. Insulated Joint.

Insulated Joints.

If for signalling reasons it is desired to cut the track rails into sections, raw hide is placed between ends of rails and wood insulators under fish plates. See Fig. 360.

STEAM OR ELECTRIC TRACTION.

No one disputes the ability of our manufacturers to build electric locomotives light enough to operate upon the present roadbed and bridges and yet possess twenty-five per cent more horse-power than its steam-powered rival.

It is admitted that these electric locomotives will haul heavier trains faster and more economically.

Owing to the huge sums of money necessary to electrify a division it is a question whether there will be sufficient saving to pay interest on and retire the debt incurred by the electrification.

As far as passenger business is concerned, probably the income from its new business (which invariably follows electrification) will be the factor, inducing companies to change over to electricity.

The more frequent service at higher schedule speed has always built up the country feeding the line and induced more traffic.

The number of people who *must* travel is increased by the higher speed (less time spent on road); the number who *want* to travel and *don't* will be reduced. This is because those sections whose distance *in time* was too great will become populated by city workers, and the number of pleasure travelers is increased as soon as the expression, "You can catch a train at any time," becomes prevalent and truthful.

At the present time the obvious solution of the question is to equip those portions of divisions where the *local traffic* is heavy with third rail and run shorter trains (not less than three cars) with motor trucks, at more frequent intervals. The through service will be carried over the same rails by steam.

At large terminal stations the through trains should be hauled to the end of the electric division by the electric locomotives and then forwarded by steam.

It will be the freight business, the expense of which goes by the train mile and its income by the ton mile, which will force trunk lines to electrify whole divisions.

As a consequence of this they will be able to furnish a high speed passenger service at less cost per car-mile than at present. The income being regulated by the passenger-mile, increased earnings will result.

There are two ways of moving a load by electricity, the *car motor* and the *locomotive* system.

For all traffic whose origin and destination is within the limits of the Electrical Division of a railroad, the car motor plan is the cheapest; and the saving in money increases with the frequency of the car's movement.

You pay interest on the cost of a coach, and it brings in no revenue, every moment it stands idle at a terminal, so that when you are paying interest on a motor equipment at the same time it becomes a matter of vital importance that these cars be kept moving.

When the electrical division exchanges through traffic with a steam division and the coaches will be away for long periods, the interest charges on idle motors becomes so great, and the amount of extra equipment, so that plenty of motor cars shall still be at home, grows so

large, that it is cheaper to concentrate a small fraction of these motors on large trucks and use them to haul the trains.

Then when the train is forwarded over the steam division the electric locomotive can lay over 15 or 20 minutes and pull the next incoming train back.

One of the economies of transportation is to make the car miles per motor as large as possible.

For freight, where traffic is interchanged with foreign roads, motor equipment on the cars is out of the question. The large portion of its life spent on sidings and in terminals makes it very doubtful whether car motors would ever pay.

For hauling freight over electric divisions some people figure that steam will do it better. I believe every one sees that long freight trains with as high a speed as is consistent with coal economy is the thing to be desired. With steam this means 12 to 15 M. P. H.

The weight of the locomotive is limited by the strength of bridges and wear and tear upon the road bed. An electric locomotive can be built weighing the same as a steam freight locomotive with 25 per cent more hauling power.

It seems then that the proper way to handle freight in an electric zone is by electric locomotives at a higher speed and less cost per ton mile.

All heavy pusher work on long steep grades would be done more economically by electric locomotives.

A road will handle its suburban business with coaches having motors in the trucks and all through traffic with electric locomotives.

The result of the electrical equipment will be several great economies:

1. In order to haul a train a steam locomotive must be made ready at an expense for labor and coal.

The new locomotive is made ready by closing one switch.

2. Burning coal in many small inefficient fireboxes means a large coal bill per ton mile of traffic moved.

Using cheaper coal in a power-house with more efficient furnaces, a gentler draft and mechanical stokers results in a great saving in coal bills.

3. A steam locomotive standing in a station or in the yard at a terminal after a run, is burning coal with no return.

The instant an electric locomotive stops, the flow of current ceases, and the moment a run is over the expense for coal drops to almost nothing. There is coal burning at the power station, but this coal is for the average load and very little of it is chargeable against an electric locomotive.

4. When a delayed locomotive attempts to make up time, coal is burned at a more rapid rate and steam is used with a longer cut-off; both of which are expensive operations.

The normal operation of an electric locomotive does not utilize the full power of the motors, and when behind schedule the full power is used *without any appreciable change in the efficiency.*

5. The total expense for two power houses, eight sub-stations, thirty locomotives and the third rail is greater than for thirty steam locomotives, but the saving in operating expenses and maintenance of way goes each month to pay the fixed charges of the plant and there is something left over to pay off the debt incurred when installing the electrification.

It is a mistake to think that the horse power of these two power houses must be the sum of the horse power of the thirty steam locomotives they are designed to replace, for all these locomotives are not running at once. The power house only has to take care of the power required for the maximum number of trains running at the same time. This information taken from a train diagram usually results in about 25 per cent of the horse power being installed for service, with some extra for reserve.

6. For the same traffic fewer electric locomotives will be needed.

The average month of a locomotive's life is made up of pulling trains 30 per cent of the time, loafing around under steam waiting for transportation department 50 per cent, under care of motive power department 20 per cent, and a little "soldiering" out on the road.

An electric locomotive is built with an idea of giving almost continuous service. They will tax the ingenuity of the transportation department to find enough work for them to do.

7. A moderate percentage of the expansive force of the steam cannot be used, for the connecting rod would tear the crank pins out. The exhaust is closed ahead of time to avoid this, and the power of engine reduced. A very annoying feature of the steam locomotive is its persistent effort to drive the rails down to China and the seat of the engineer's overalls upwards, due to the flinging effect of any unbalance in the parallel rods and crank pins.

The electric locomotive with its purely rotative motion is very easy on the track, and saves many dollars of expense.

Selection of Equipment.

The type of motors being fixed upon, the actual horse power to be installed on locomotives or cars is determined by consideration of:

1. Schedule speed.
2. Number of miles between stops.
3. Rate of acceleration.
4. Maximum speed.
5. Weight of trains.
6. Grades and curves of track.

The New York Central demanded for its through traffic a locomotive which must be capable of running from Grand Central Station to Croton (34) miles hauling a total train weight of 435 tons in 44 minutes without a stop. To attain on a tangent track with this train a speed of not less than 60 M. P. H. Speed in excess of 65 M. P. H. under these conditions not desired.

To be able to pull a train of 875 tons, making same schedule speed as is at present made with steam locomotives.

Let us ourselves roughly design a locomotive and see how things turn out.

Required the weight and horse-power of an electric locomotive capable of hauling itself and 8 cars of 65 tons each up a 1½% grade at 50 M. P. H., at the same time rounding a curve of 2 degrees; also capable of starting this train from a station on a tangent and level track, in a less time than the present steam locomotives.

To haul a train we must overcome the friction in journal boxes and between wheels and rails; the air resistance and the side thrust of curves. We must apply

enough power to actually lift the train against the force of gravity up any grades.

For every 1% of grade it takes 20 lbs. to pull 1 ton up it. Every 1° of curvature requires 0.7 lbs. per ton to draw train around. These figures are in addition to the pull required for the train friction and air resistance at the particular speed in question.

1% grade needs 20 pounds per ton.
1° curve needs 0.7 pounds per ton.
50 M. P. H. needs 13 pounds per ton.

Hence for our conditions we need

For grade	1½×20=30.0	lbs. per ton.
For curve	2×0.7= 1.5	lbs. per ton.
For speed	=13	lbs. per ton.
Total	44.5	lbs. per ton.

8 cars at 65 tons=520 tons.

The pull required at the draw bar of the locomotive will be 44.5×520=24,000 lbs. draw bar pull.

The locomotive must brace its feet (drivers) against the road bed (rails), and, having no hoofs to dig in, must develop its grip by pure friction. Usually steel tires against steel rails grip with only ¼ the weight upon them. Figuring on the safe side, call this 1/5, and we have the weight of the locomotive *resting on the drivers,* which must be 5 times the draw bar pull.

This calls for 60 tons on the drivers, but since probably ¼ the total weight of the locomotive will rest on the trucks, the total weight will be about 80 tons, in order to get sufficient *adhesion* to pull the load.

This 80 tons will need 80×45 or 3,600 lbs. to propel

itself. The *tractive force* to be exerted at the rail head will be 24,000+3,600 or 28,000 lbs. in order to haul the total train weight of 520+80=600 tons. There will be 24,000 lbs. draw bar pull exerted to haul the coaches.

The horse power to be installed in this locomotive under the given conditions will be the same as if it were steam driven, *i. e.*, 5 H. P. per ton of train or 5×600= 3,000 H. P.

If this locomotive can accelerate a train from a stop on a level, straight track faster than a steam locomotive, it will be satisfactory.

It takes 90 lbs. per ton to increase speed at rate of 1 M. P. H. P. S. on this kind of track. The tractive effort of the locomotive is 28,000 lbs., and dividing by train weight 600 tons gives 46 lbs. per ton to start train on level. 46 is half of 92, so we can accelerate at ½ M. P. H. P. S., which beats a steam locomotive.

The 35 locomotives which the General Electric Company, aided by the American Locomotive Company, built to fit these requirements were found to weigh 100 tons and the power installed was four 550 H. P. motors or 2,200 H. P. in all. These motors are capable of delivering 3,000 H. P. continuously for long periods of time.

Since the conditions of speed, grade, and curve in this problem do not occur very often at the same time, nor even then for long periods, this motor equipment is sufficient.

A view of this locomotive is given in Fig. 361.

The principal dimensions of the locomotive and other data regarding it are given below, and for sake of comparison, the corresponding dimensions of a standard high speed steam locomotive of the Atlantic type are printed in a parallel column.

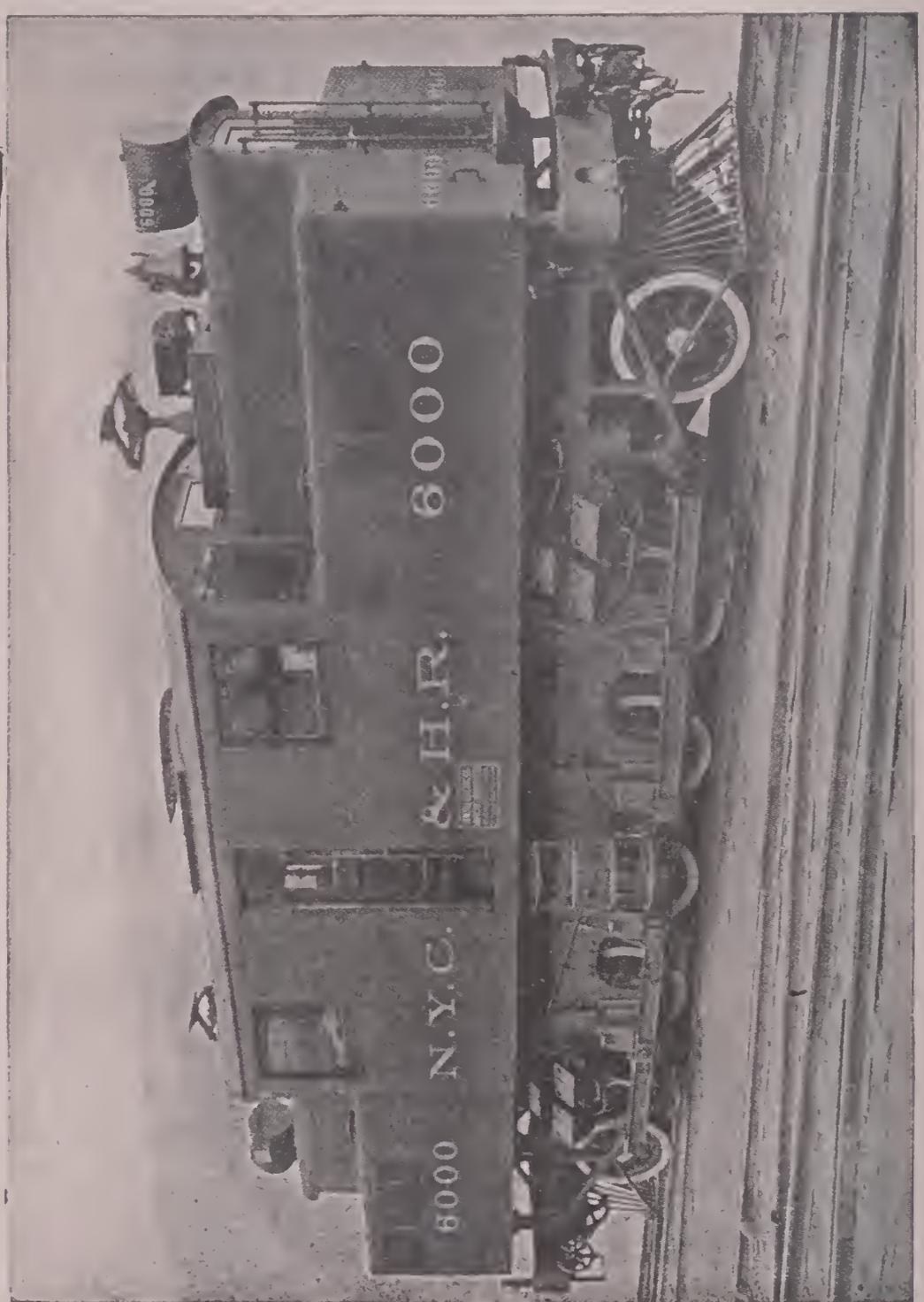


Fig. 361. New York Central Electric Locomotive.

COMPARATIVE DATA OF ELECTRIC AND STEAM LOCOMOTIVE.

ELECTRIC.

No. of driving wheels	8
No. of truck wheels	4
Weight	95 tons.
Weight on drivers	68 "
Wheel base, driving	13 ft.
" " total	27 "
Max. tractive power (draw-bar pull)	34,000 lbs.
Tractive power per ton engine weight	330 "
Wheels, driving	44 in.
" engine truck	36 "

STEAM.

No. of driving wheels	4
No. of truck and tender wheels.	14
Weight { Engine, 100 tons / Tender, 61 " }	161 tons.
" on drivers	55 "
Wheel base, driving	7 ft.
" " engine	27 ft. 9 in.
" " engine and tender	53 ft. 8 in.

Maximum tractive power.	27,500 lbs.
Tractive power per ton engine weight	171 lbs.
Wheels, driving	79 in.
" engine truck	36 "
" trailing	50 "
" tender	36 "

The following additional data apply to the electric locomotive of the New York Central R. R.:

Length over buffer platforms	37 ft.
Extreme width	10 "
Height to top of cab	14 ft. 4 in.
Diameter of driving axles	8.5 in.
Normal rated power	2200 H. P.
Maximum power	3000 H. P.
Speed with 500-ton train	60 m.p.h.
Voltage of current supply	600
Normal full load current	3050 amperes.
Maximum full load current	4300 amperes.
No. of motors	4
Type of motor.	GE—84—A
Rating of each motor	550 H. P.

It is most interesting to note the differences as tabulated below:

	Steam.	Electric.	Difference in favor of electric.
Length over all.....	67 ft. 7¾ ins.	36 ft. 11¼ ins.	30 ft. 8½ ins.
Total weight (including tender for steam locomotive	342,000 lbs.	200,500 lbs.	141,500 lbs.
Concentrated weight on each driving axle.	47,000 lbs.	35,500 lbs.	11,500 lbs.
Revenue bearing load back of locomotive...	256 tons	307.25 tons	51.25 tons
Acceleration M.P.H.P.S. averaging up to 50 M.P.H.....	.246	.394	.148
Time required to reach speed of 50 M.P.H.	203 sec.	127 sec.	76 sec.

Fig. 362 shows the comparative distribution of weight for electric and steam locomotives.

The New York Central demanded motor cars which would be able to improve the general suburban traffic conditions, and practically asked for the best equipment which could be furnished them.

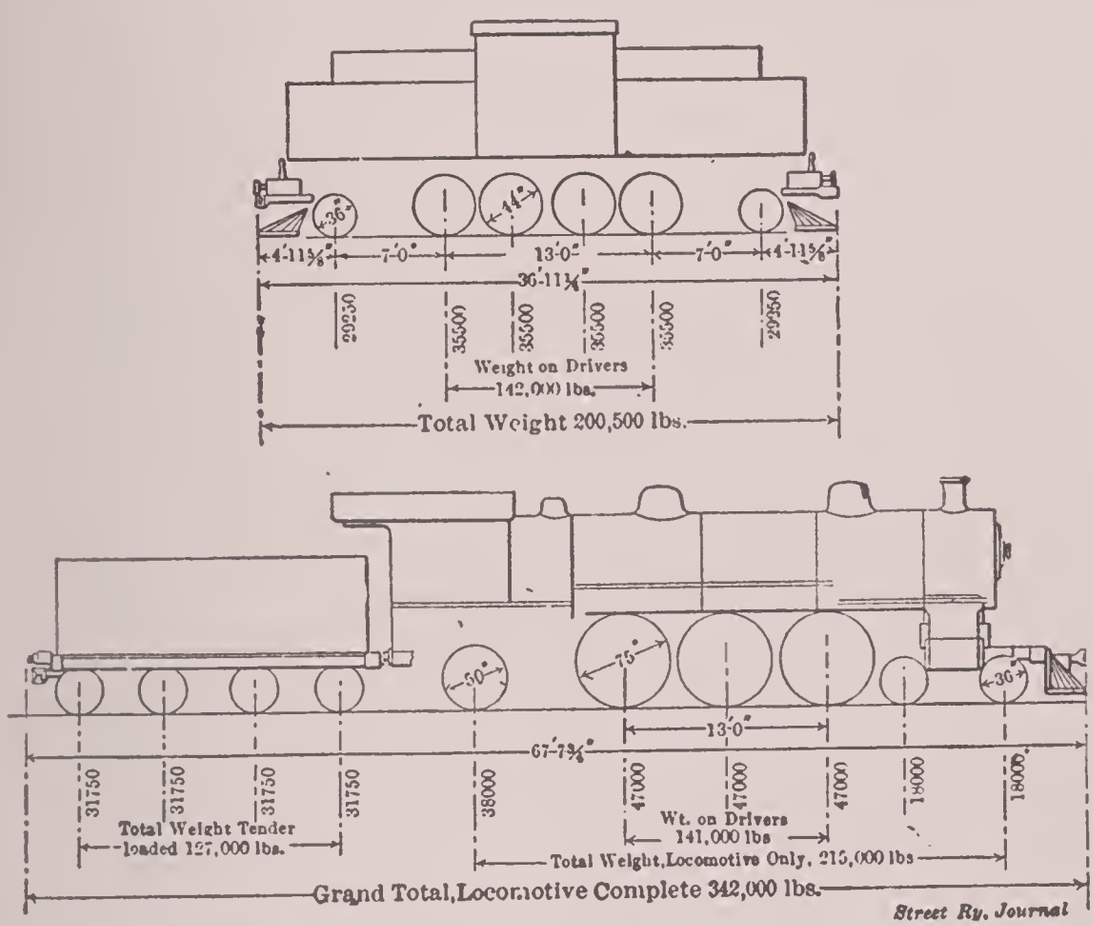
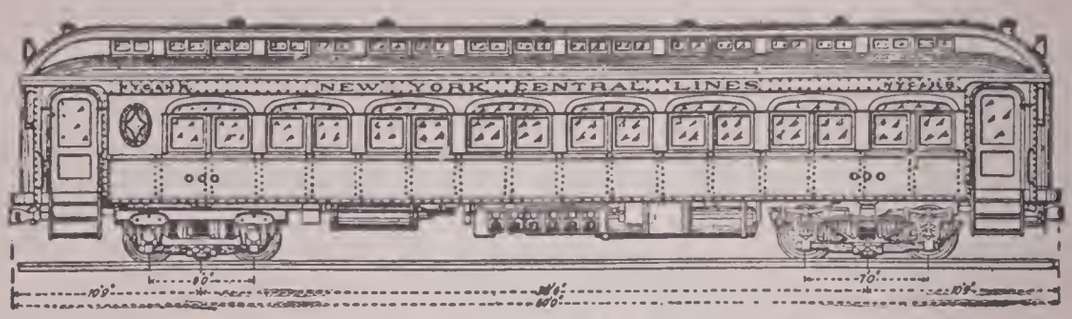


DIAGRAM OF COMPARATIVE WEIGHT DISTRIBUTION ELECTRIC AND STEAM LOCOMOTIVES

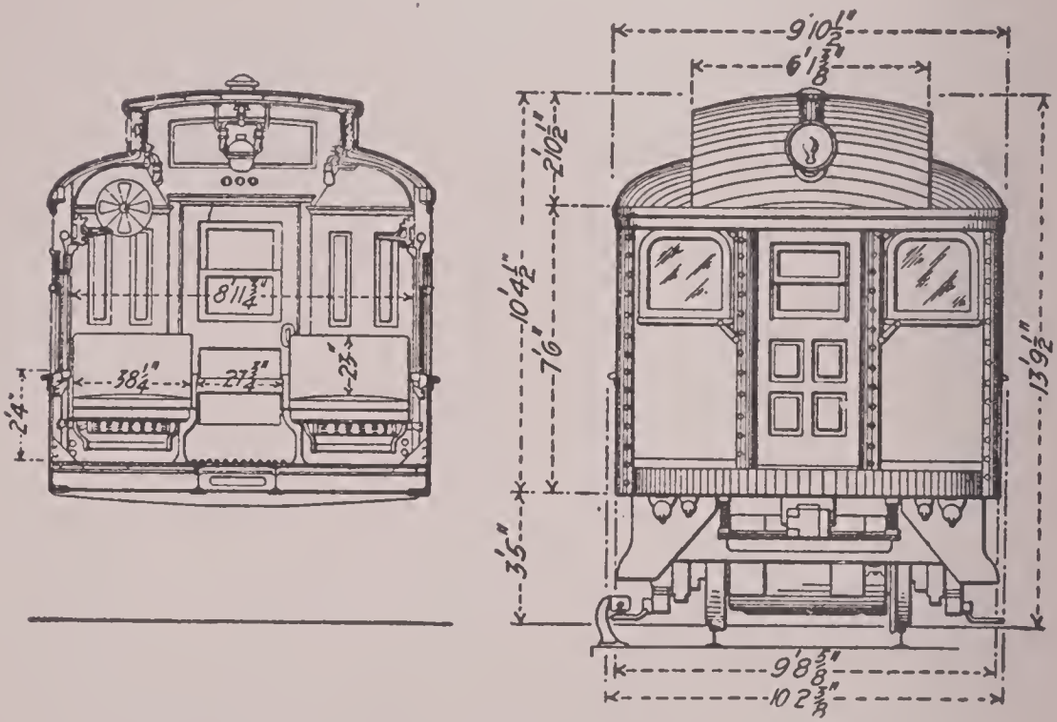
Fig. 362.

This resulted in the building of 125 steel cars (Fig. 363) shown in end view by Fig. 364, which are fitted with the Sprague-General Electric multiple unit system of control, known also as Type M control.



LONGITUDINAL ELEVATION OF NEW YORK CENTRAL STEEL MOTOR CAR

Fig. 363. New York Central Steel Motor Car.



CROSS-SECTION AND END VIEW OF NEW YORK CENTRAL STEEL MOTOR CAR

Fig. 364.

They weigh 51 tons each. Under one end is a M. C. B. trailer truck (with no motors), under other end is a motor truck, both built by American Locomotive Company. The motor truck has two 200 H. P. motors weighing six tons each, geared to wheels by a 2:1 gearing. The trailer wheels are 33 inch, the motor truck wheels 36

inch. There are five tons of electrical equipment on each car besides the motors. They can accelerate at rate of 1.25 miles per hour per second and attain a maximum speed of 52 miles per hour.

A. C. or D. C. TRACTION.

The question as to which is the best A. C. or D. C. systems of traction should not be one of heated argument, as it often is; but rather one of plain presentation of facts, and the drawing of a logical conclusion from them.

For some circumstances an A. C. system is the proper solution of the problem; for others a D. C. system is best; while in still other situations nothing but a combined A. C.-D. C. system will do the work.

The general advantages and disadvantages of each system will be given and a few general conclusions drawn.

A. C. System.

Advantages:

(1) A high voltage may be used allowing use of small feeders and trolley wires.

(2) Distance between power houses may be great, hence only a few are needed. Several large power houses are cheaper to build and operate than a greater number of smaller ones.

(3) The control of speed of train is by "potential control;" this is cheapest method.

Disadvantages:

(1) The trolley must be an over-head system. The conductivity of a third rail for A. C. is low.

(2) A breakage of trolley which might occur (not very likely to happen) would be *very* dangerous to life.

(3) A stiff, non-swaying overhead trolley is as expensive as a third rail.

(4) A. C. motors do not get a train up to speed as quickly as D. C. motors.

(5) To develop same power on A. C. from the same weight of motor, as could be done on D. C. with same weight of material, motors must be cooled by air blast. (This helps to keep dust out.)

(6) Not adapted to freight pusher work as A. C. motors cannot stand still and push.

D. C. Systems.

Straight D. C. or A. C. Transmission.

Advantages: All D. C. systems:

(1) Train gets up to speed very rapidly.

Disadvantages:

(1) Power is delivered to train at 600 volts so feeders and trolley (if used) are large.

Straight D. C. System.

Advantage:

(1) Simple; well understood.

Disadvantages:

(1) Transmission at low voltages makes distance between power houses small.

A. C. Transmission, D. C. Utilization.

Advantages:

(1) Transmission by A. C. high voltage is cheap.

(2) Few power houses required.

(3) D. C. motors used have good acceleration, *i. e.*, get up to speed quickly.

Disadvantages:

(1) Rotary converters must be used.

Conclusions.

It seems from this summary that when getting up to full speed quickly is desired, the D. C. motor should be used. For any economy A. C. transmission should be used.

Let us see if the quick "get away" from stations is of much importance to the operation of a railroad.

The technical name for rate of speed increase is *acceleration.* By this I mean the *increase in speed* in miles per hour which occurs every second from the start from rest until the train reaches its maximum speed.

If a train pulls out of a station and steadily increases its speed, finding itself going at 50 M. P. H.* 203 seconds later, it is evident that *each second* it went 0.246 M. P. H. faster than the previous one, for $0.246 \times 203 = 50$.

If some other train accelerates at the rate of 0.394 M. P. H. per second, it will take 127 seconds to attain a speed of 50 M. P. H.

---

*M. P. H.=Miles per hour.

Acceleration must be high, else the schedule speed for a given maximum speed will be too low, and the time occupied running between stations too long. It cannot be too high, as it would be uncomfortable for passengers, and would require much larger motors, which would not be needed as soon as train was at full speed.

The great virtue of an electrically driven or hauled train is its ability to accelerate rapidly.

For example, let an electric train be capable of accelerating at rate of 0.4 and a steam train at 0.25 M. P. H. P. S.* Suppose both can run at a maximum of 50 M. P. H., but no higher. They start together at a station and run to the next station three miles away.

The steam train takes 200 seconds to arrive at 50 M. P. H. and therefore moves 200 seconds at an *average speed* of 25 M. P. H. or 36.6 F. P. S., and in getting up to speed it passes over 200×36.6 or 7,320 feet. Allowing 2,500 feet for stopping train, there are 6,020 feet to traverse at 50 M. P. H. or 73.2 F. P. S.

73.2÷6,020 gives 82 seconds.

The stop will take 67 seconds.

Total Time—Steam Train.

200 seconds accelerating over	7,320	feet
82 seconds free running over	6,020	feet
67 seconds braking over	2,500	feet
349 seconds over	15,840	feet

5 min. 49 secs. for 3 miles.

*M.P.H.P.S.—Miles per hour per second.

Total Time—Electric Train.

125 seconds accelerating over	4,575	feet
120 seconds free running over	8,765	feet
67 seconds braking over	2,500	feet
312 seconds	15,840	feet

5 min. 12 secs. for 3 miles.

The difference in time is 37 seconds in favor of the electric train.

In a suburban run of 33 miles with stations every 3 miles, this saving of time is repeated 11 times and the gain in schedule time for the run is 6¾ minutes.

This is assuming what is quite true; that curves, grades, slow downs for signals, stops at stations, will equally affect each train.

When the stations are closer together the saving is even greater. For a two mile interval the log of runs works out as follows:

Total Time—Steam Train.

200 seconds accelerating over	7,320	feet
10 seconds free running over	740	feet
67 seconds braking over	2,500	feet
277 seconds	10,560	feet

4 min. 37 secs. for 2 miles.

Total Time—Electric Train.

125 seconds accelerating over.....	4,575	feet
48 seconds free running over.....	3,485	feet
67 seconds braking over.....	2,500	feet
240 seconds.....	10,560	feet

4 minutes for 2 miles.

Gain for electric train, 37 seconds.

In a run of 34 miles with two mile station intervals there would be a clear gain of 10½ minutes by electric operation.

To show that this is not a mere paper result, I am showing Fig. 365. This run took place last April on the Mohawk Division of the New York Central, out at Wyatts, just west of Schenectady. The two trains were each of six cars of equal weight. The electric locomotive was No. 6000 and the steam locomotive No. 2797. From the standing start No. 6000 accelerated the more rapidly, and at 1,500 feet from the starting point this photograph was taken. Three and a half minutes after the start No. 6000 was 2,500 feet ahead.

It will thus be seen that for suburban service, where the stations are close together, the acceleration is the most important feature and considerable expense and perhaps even complication may be incurred in order to get good acceleration.

This same argument that an electric motor is better than a steam engine for suburban service holds good to a lesser degree, that a motor driven by D. C. is better for

suburban service than one driven by A. C., because the D. C. motor accelerates the faster.

The advantage of the D. C. motor in this respect begins to be of less consequence as the distance between stations increases. For express train service there is practically no difference in the schedule speeds that they can maintain.

Fig. 365. Acceleration Test between No. 6000 and Pacific No. 2797.

Notice that the longer the runs between stations, the nearer the schedule speed approaches the maximum speed which is attained during free running.

However, the whole story between D. C. and A. C. motors in suburban service is not yet told.

Locomotives making an acceleration of 0.4 or with short trains of 0.5 M. P. H. P. S. are worthless in a

suburban service compared with trains of motor cars making an acceleration of 1.25 M. P. H. P. S., for this three times as great acceleration makes an enormous difference in schedule speed.

With D. C. motors these motor cars can be run in trains and controlled as easily as a single car.

A certain timidity is felt about bringing an 11000 volt A. C. circuit down through a car full of people. About 3,000 volts is all the engineers have screwed up their courage to. But at 3,000 volts the A. C. system has lost all its advantages as regards low cost. It is no cheaper than D. C. It being understood that in A. C. case 11000 volts are reduced in sub-stations to 3000 for trolley, and in D. C. case 11000 volts A. C. are reduced in sub-stations to 600 D. C. for third rail.

Hence we must compare D. C. motor car trains at high acceleration to A. C. locomotive drawn trains at low acceleration.

I think it will be seen that systems using A. C. motors in the present state of the art are not suitable for suburban service on steam roads.

It will be equally obvious that for express service or trunk line operation, the simplicity of the straight A. C. system with 11000 volt trolley and locomotive drawn trains is the better system.

Locomotives or Motor Cars.

The choice between these two depends on whether through or local traffic is to be handled.

The motor car can accelerate at 1.25 M. P. H. P. S. No locomotive could do this, for it could not be made

heavy enough to get the requisite adhesion, without breaking down all the bridges.

Such a locomotive would need 200 tons on its drivers. No existing bridges could stand the strain.

But if we take a 600 ton train of cars, the weight being distributed can be borne. By putting the motors on trucks at one end of each car we get half the weight or 300 tons for adhesion, which is more than is needed.

Motor car trains are then a necessity for suburban traffic.

LESSON 34.

Systems of Control.

The control of speed of train is by means of a controller, which throws grids of resistance in or out of motor circuits for D. C. motors; connects motor to different taps of the transformer for A. C. motors; and interchanges the relations of armature and field terminals for either A. C. or D. C. motors.

A control with resistances alone must be used when there is but one motor, as in some mine and factory locomotives. This is called *rheostatic control.*

When there are two motors we may place both in series, giving each motor 250 volts, for half speed, and both in parallel, giving each motor full voltage for full speed.

Acceleration is controlled by use of grid resistances, made of cast iron, shown in Fig. 366. These are cut in the circuit at start by controller and cut out one by one while accelerating to full series; they are then cut into the circuit with the two motors in parallel and again cut out one by one until motors are in full parallel. Thus at the two free running speeds there are no resistances in circuit.

This is called the *series-parallel control.*

When A. C. is used the voltage applied to the motors is varied by connecting more or less of the secondary turns of the step down transformer to the motor. This is called *potential control.*

The series-parallel control is the most familiar to us, for the two K controllers shown in Figs. 367 and 368 are regular equipment on many interurban lines.

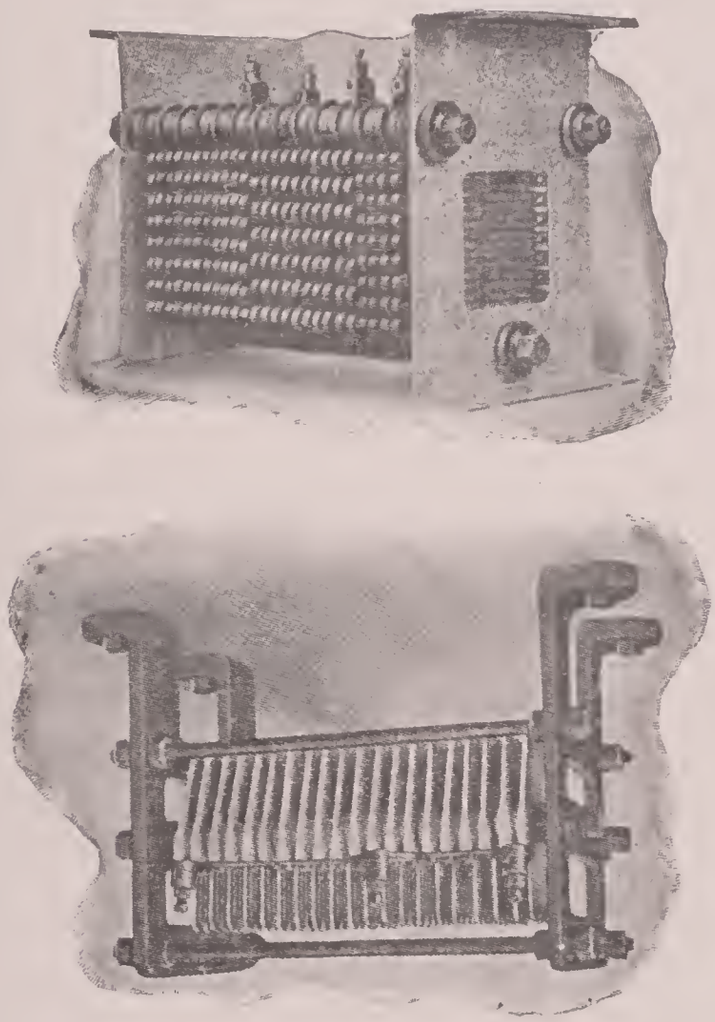


Fig. 366. Cast Iron Grid Resistances.

The letter K designates a controller which never opens the circuit from time motors are started till they are in full parallel or multiple (two names for same thing).

For very heavy equipments the K controller takes the form of Fig. 369, where the cylinder is gear driven.

The letter L used in connection with controllers means

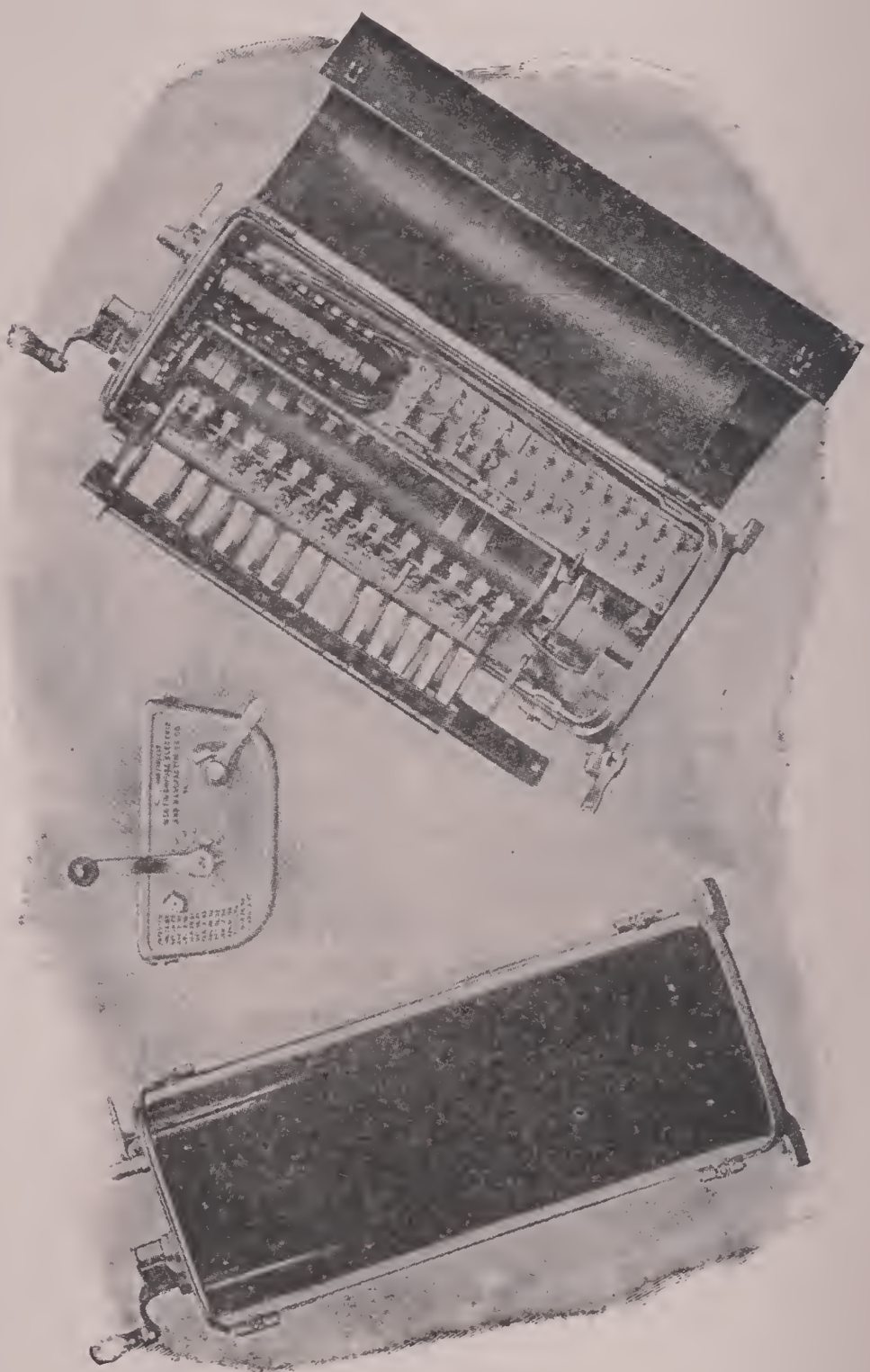


Fig. 367. K Controller.

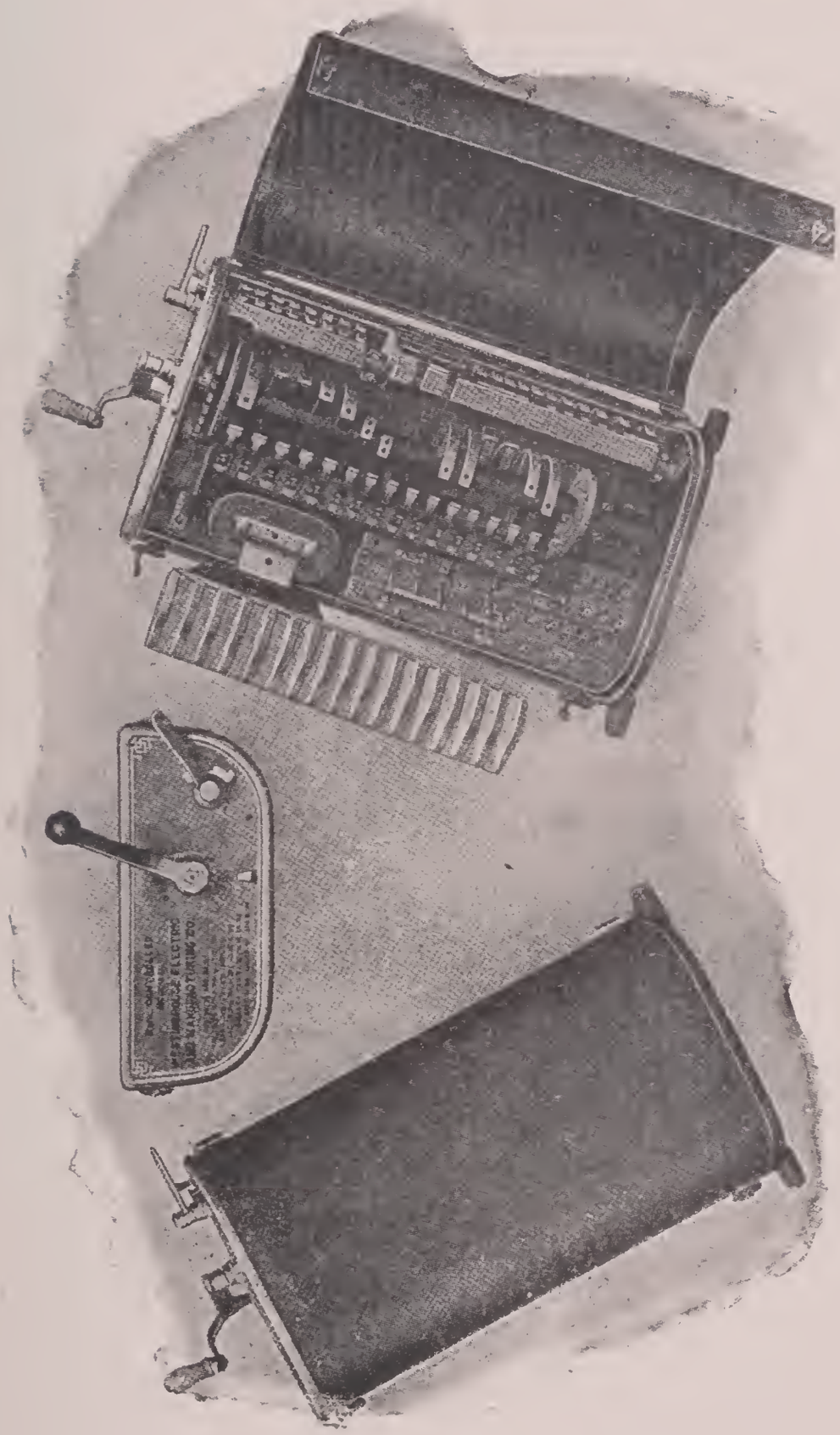


Fig. 368. K Controller.

that when changing motors from full series to parallel with resistance the circuit is momentarily opened. Fig. 370 shows such a controller.

When fitted for electrical braking the letter B is used to designate the type of controller. See Fig. 371.

Fig. 372 shows the electrical connections made by a K controller with two motors.

The notches of a controller are the positions of handle where a spring pawl drops into notches on a plate so as to hold the handle against vibration or slight pressure. The notches are named resistance, running and transition notches.

A resistance notch is one where some resistance is in circuit. These should only be used for very short periods of running. It not only wastes power to use them, but by getting the resistance grid red hot may warp it or might even start a fire.

The running notches are those where there is no resistance in circuit and the motors are in an arrangement suitable for continued use.

A transition notch is where the motors are in some combination so unsuitable for delivering power, that the notch should be passed over quickly.

All notches except transition ones are indicated on top of controller.

Fig. 373 shows connections made by a K controller with four motors.

Fig. 374 shows connections made by an L controller with two motors. The points to be noticed are: The gradual decrease of the resistance* in circuit, it taking

*The decrease of resistance is shown in a novel way by placing more of them in parallel. In diagram the wider the resistance, the lower it is.

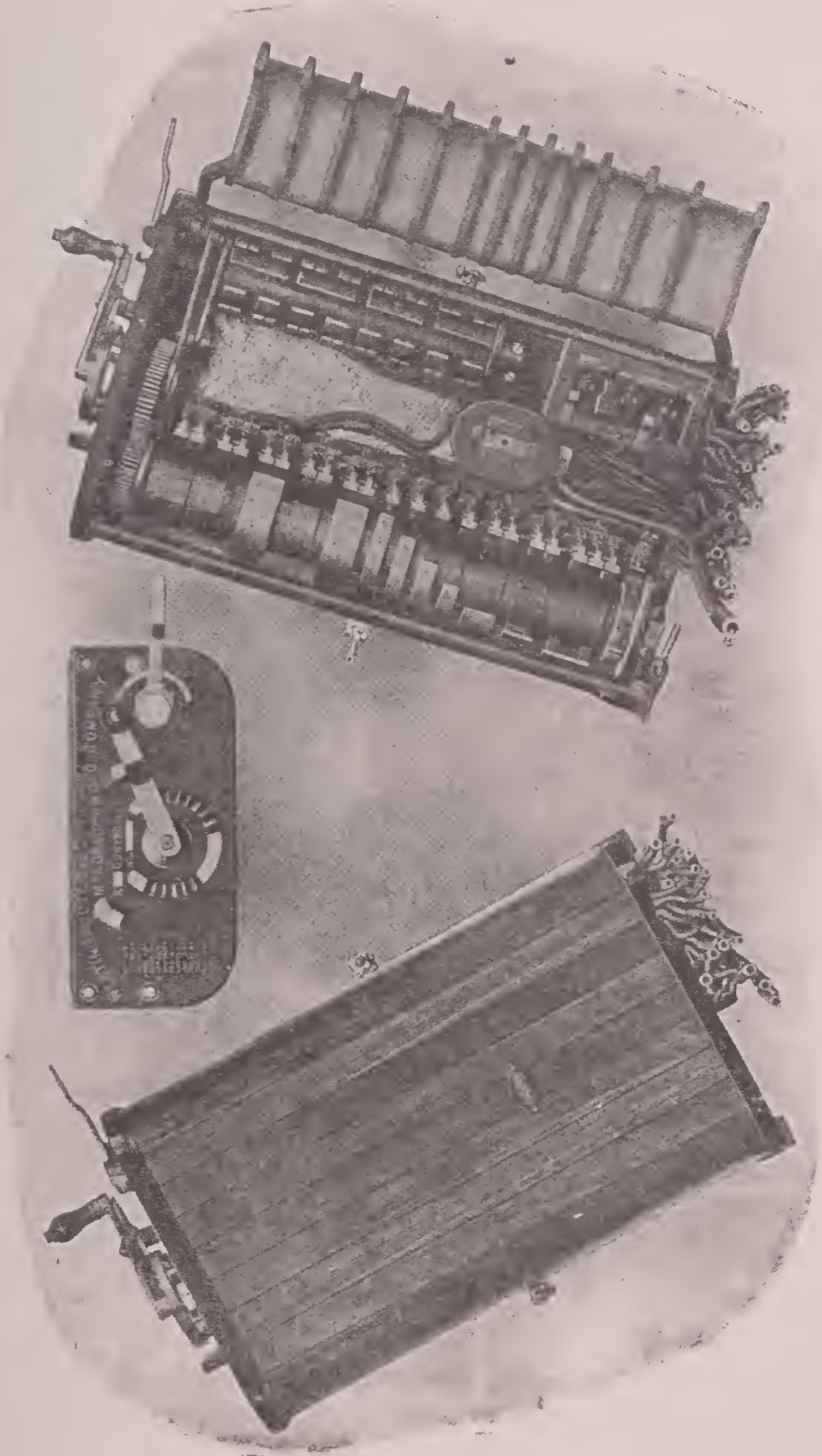


Fig. 369. K-B Controller.

12 notches to get a full series. There are a lot of resistance notches called transition notches simply because there are no marks on top on controller to indicate them Note the opening of circuit at notch 12½.

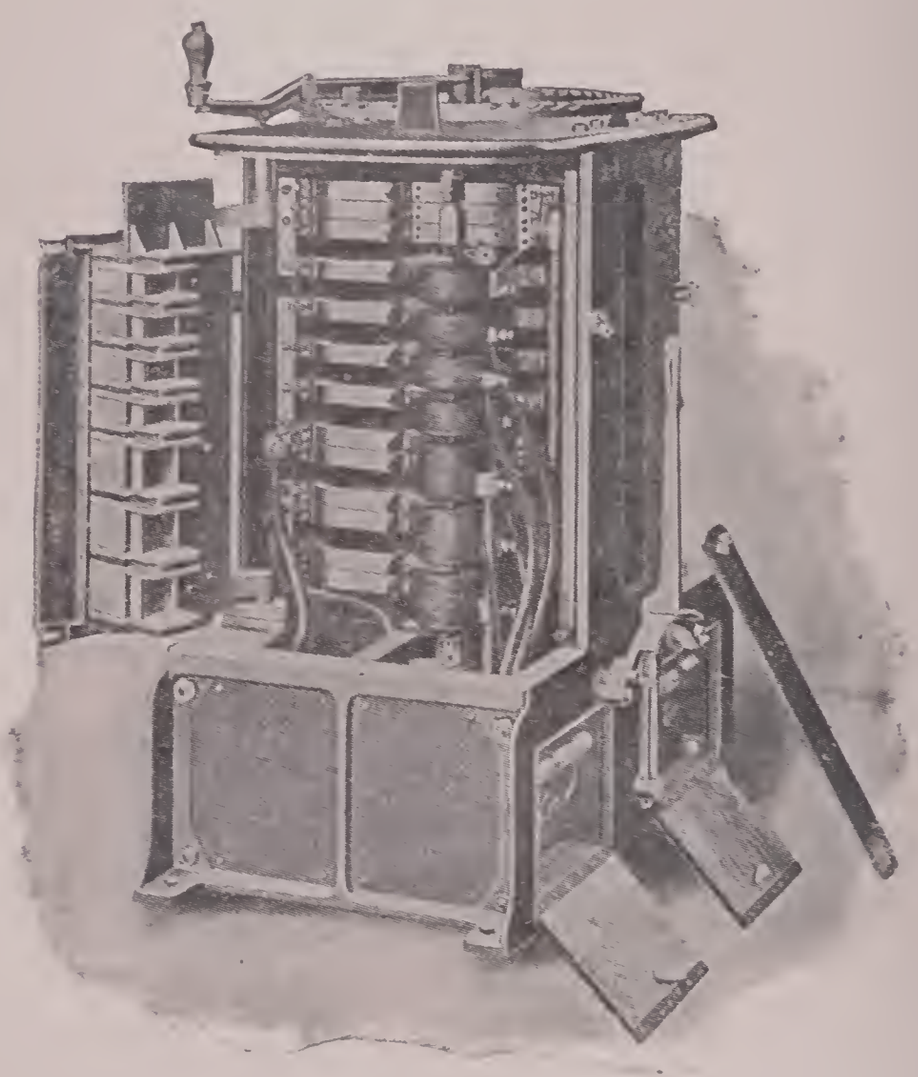


Fig. 370. L Controller.

The student should number the multiple notches up tc 24 himself.

Fig. 375 shows the connections made for electrical braking when two and four motors are used.

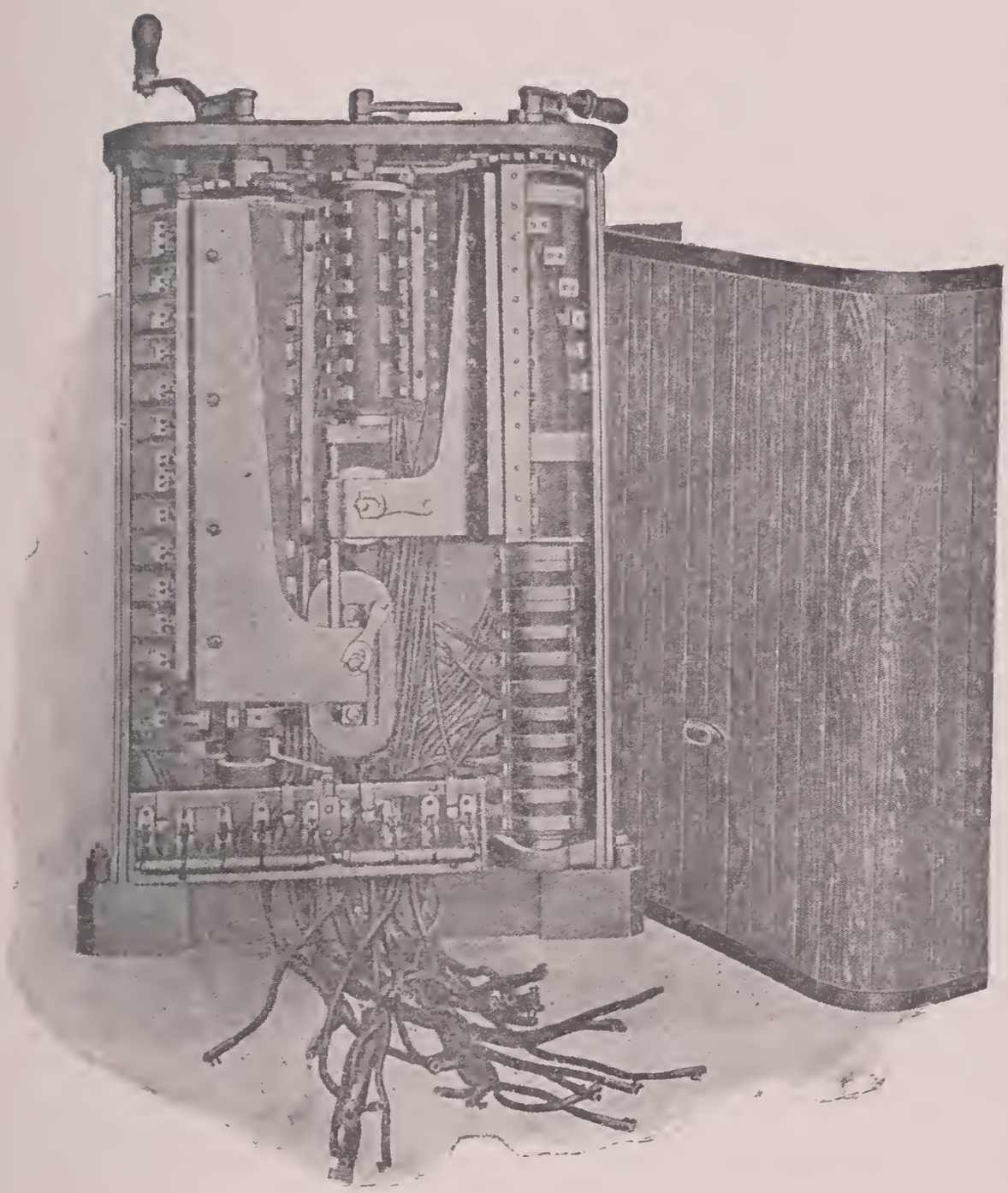


Fig. 371. B Controller.

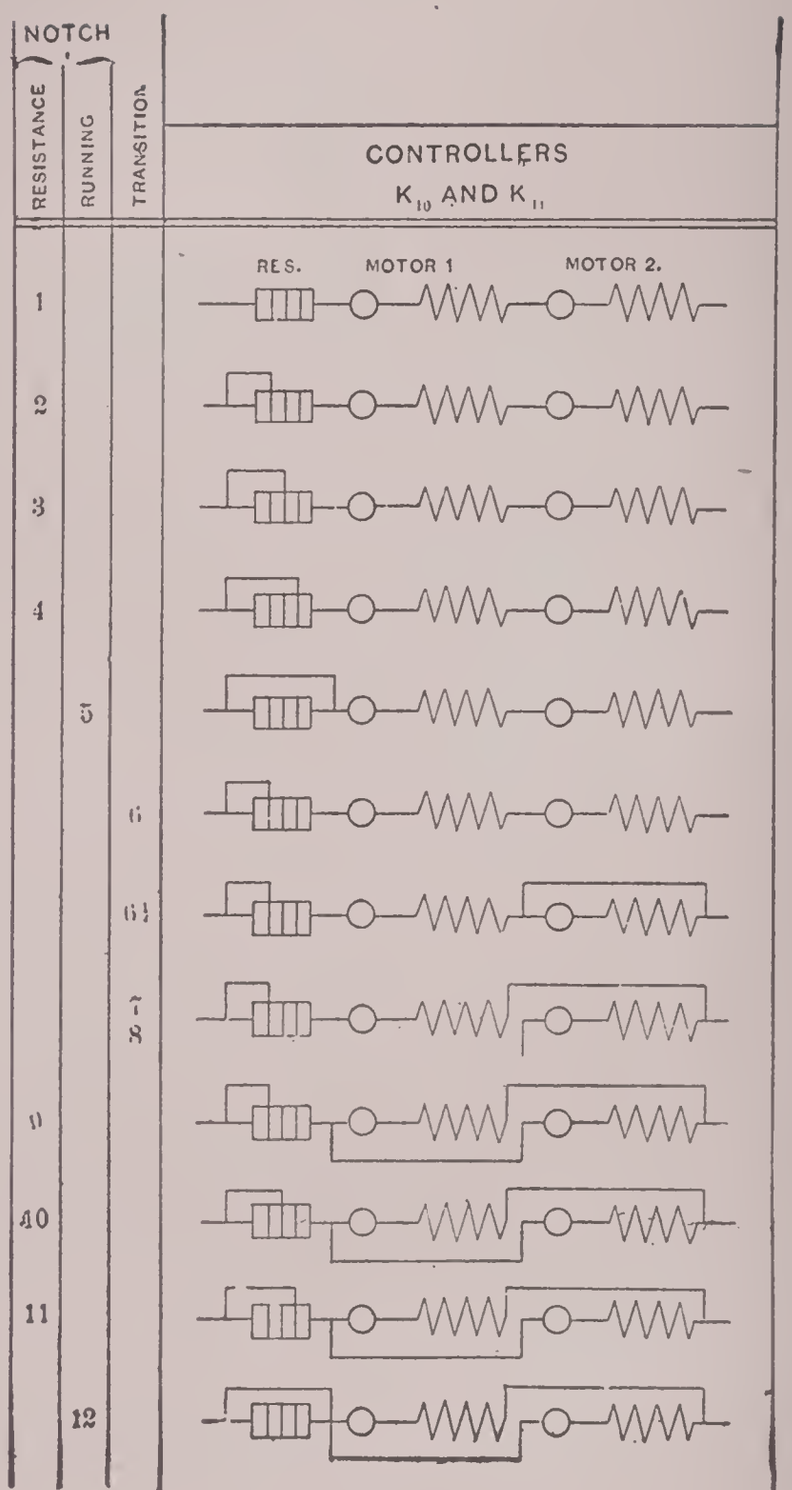


Fig. 372. Scheme of K Control with Two Motors.

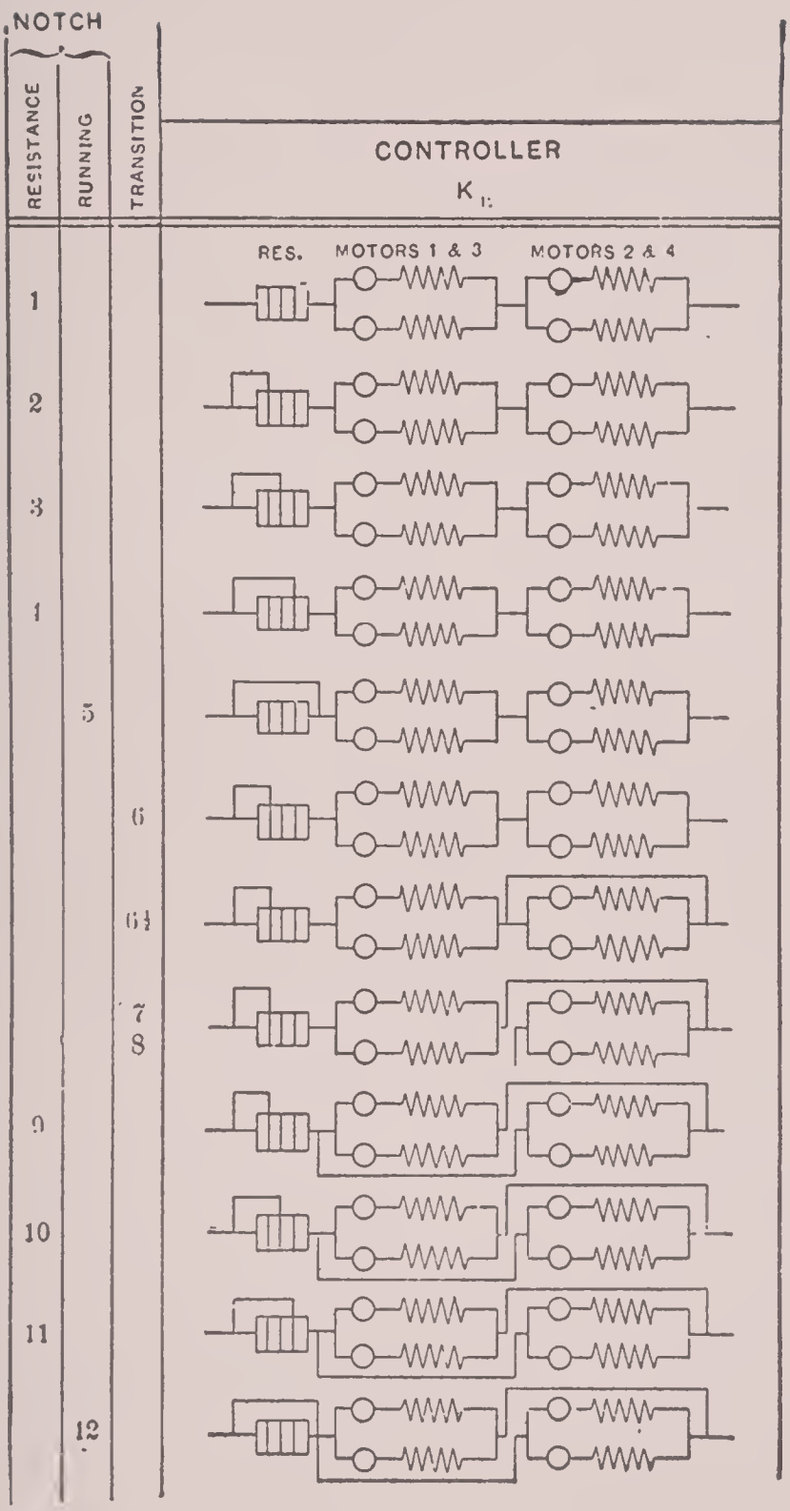


Fig. 373. Scheme of K Control with Four Motors.

Electrical braking uses the motors more than simply running the car, and so they heat more. This means a larger motor for the same schedule speed.

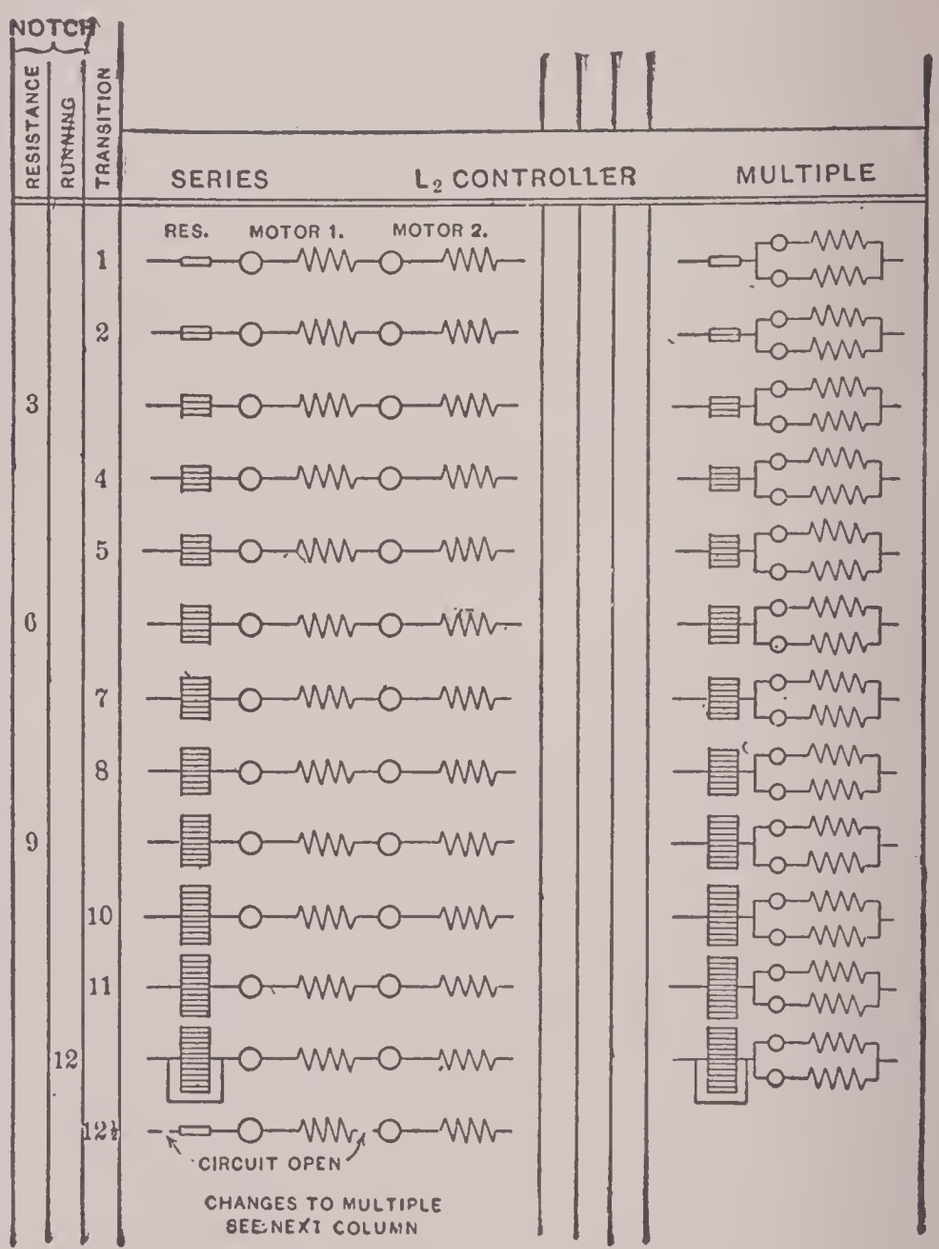


Fig. 374. Scheme of L Control.

In some controllers the movement of the hand is mechanically connected to the cylinder. Such a control is a *manual* control.

In other cases the controller merely arranges contacts which energize circuits to electro-magnetically operated switches called contactors; or electro-magnetic valves

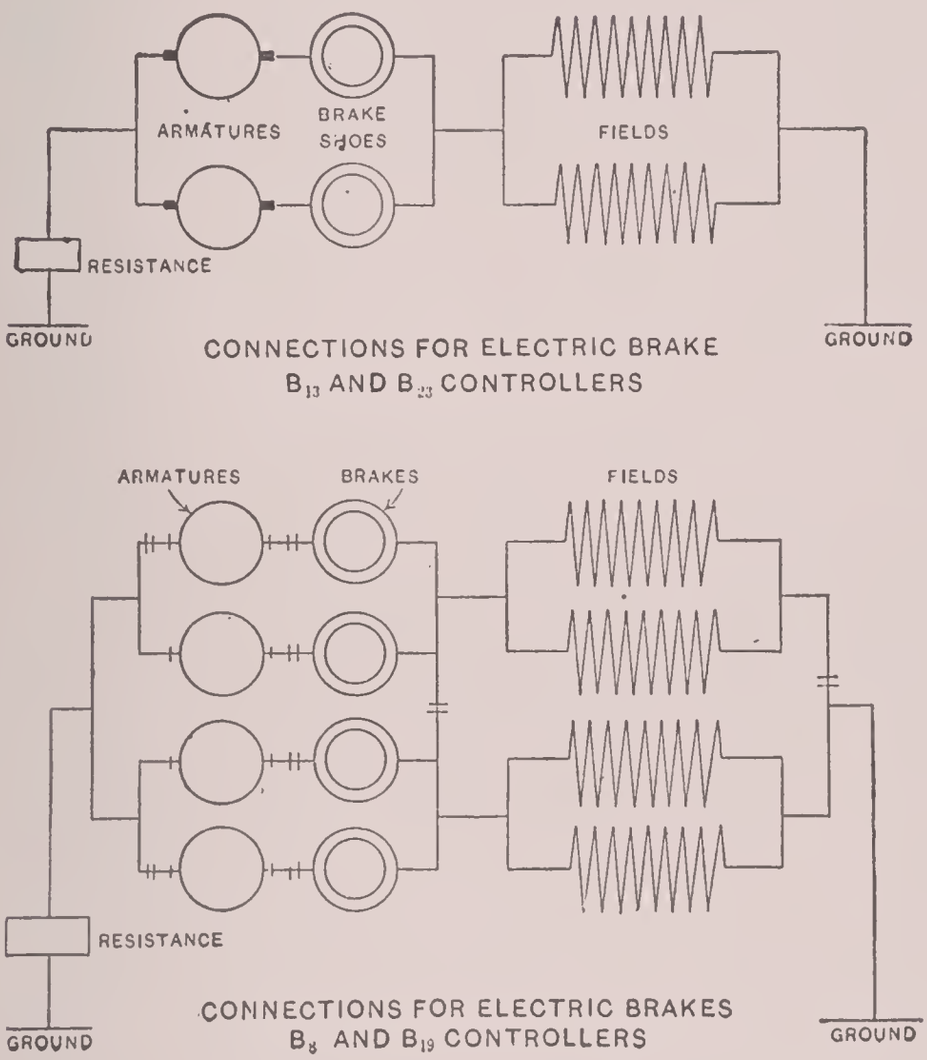


Fig. 375. Scheme of Electrical Braking Connections.

are operated which in turn operate pneumatic cylinders. The push rods from these cylinders open and close the switches. Controllers of this class are called *master controllers.*

LESSON 35.

The Sprague General Electric Type M Control.

The Sprague-General Electric Type M Control is designed primarily for the operation of a train of motor and trail cars, coupled in any combination and the whole operated as a single unit from any controller on the train. The system may also be used to advantage on individual equipments and locomotives.

The control apparatus for each motor car may be considered as consisting essentially of a motor controller and a master controller.

The motor controller comprises a set of apparatus (Fig. 376) usually located underneath the car (Fig. 377), which handles directly the power circuits for the motors, connecting them in series and parallel and commutating the starting resistance in series with them. This motor controller is operated electrically, and its operation in establishing the desired motor connections is controlled by the motorman by means of the master controller, Fig. 378, which is similar in construction to the ordinary cylinder controller and is handled in the same manner. Instead of effecting the motor combinations directly, however, this controller merely governs the operation of the motor controller.

The master controller operates a number of electrically operated switches, or "contactors," which close and open the various motor and resistance circuits, and an electrically operated "reverser" that connects the field

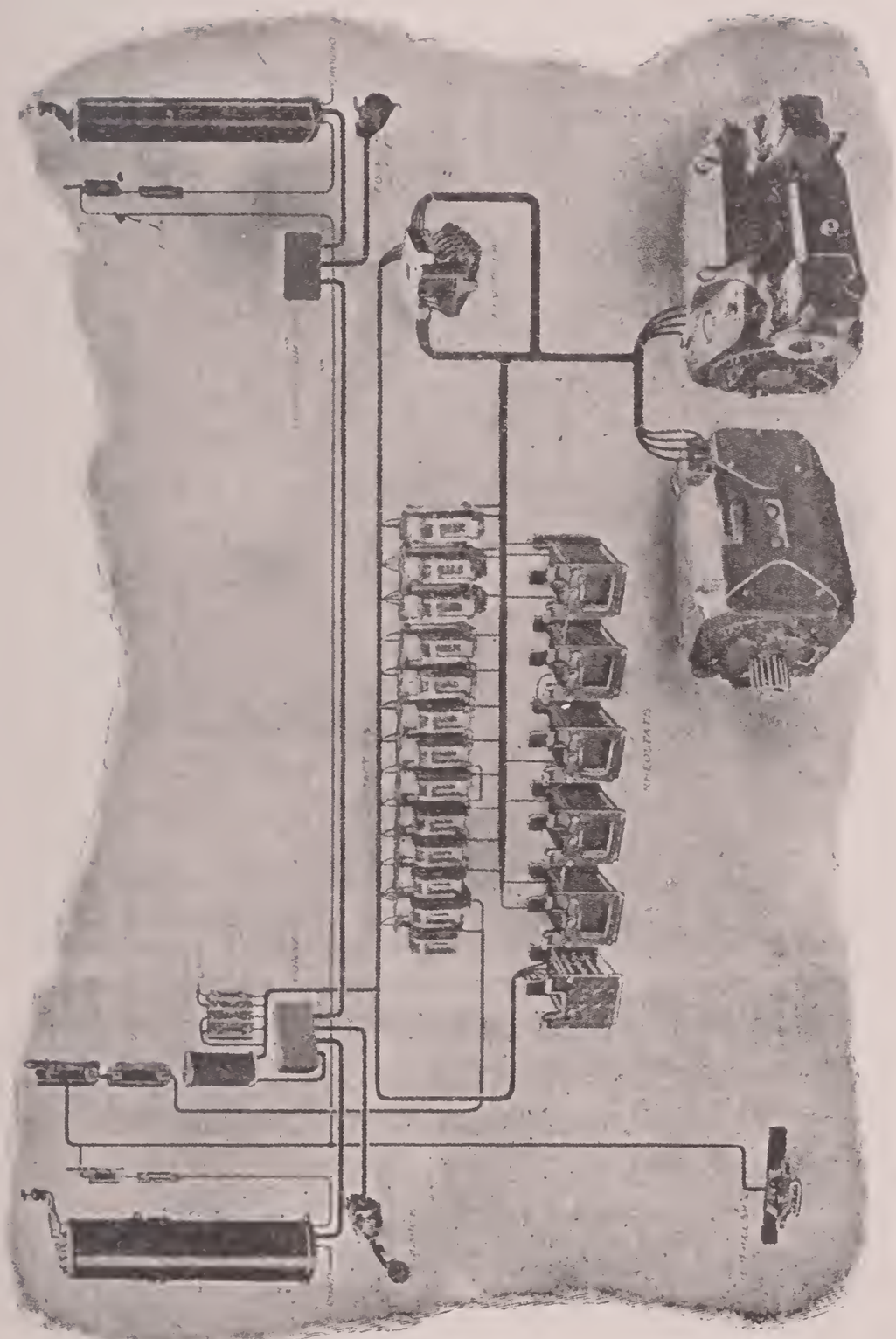


Fig. 376. General View of Apparatus Type M Control.

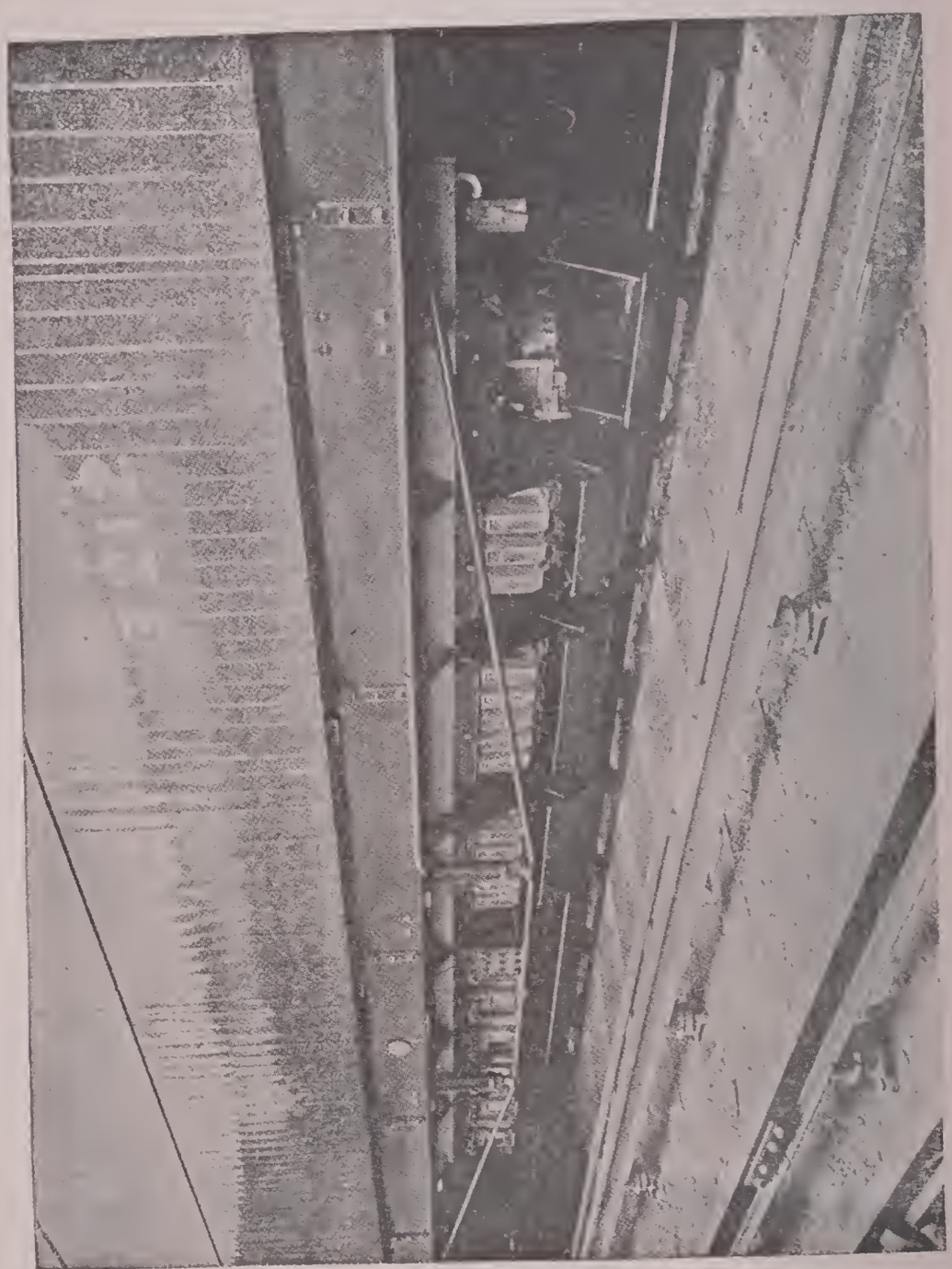


Fig. 377. Arrangement of Control Apparatus Under Car.

and armature leads of the motors to give the desired direction of movement to the car. Both the contactors and reverser are operated by solenoids, the operating current for which is admitted to them by the master controller.

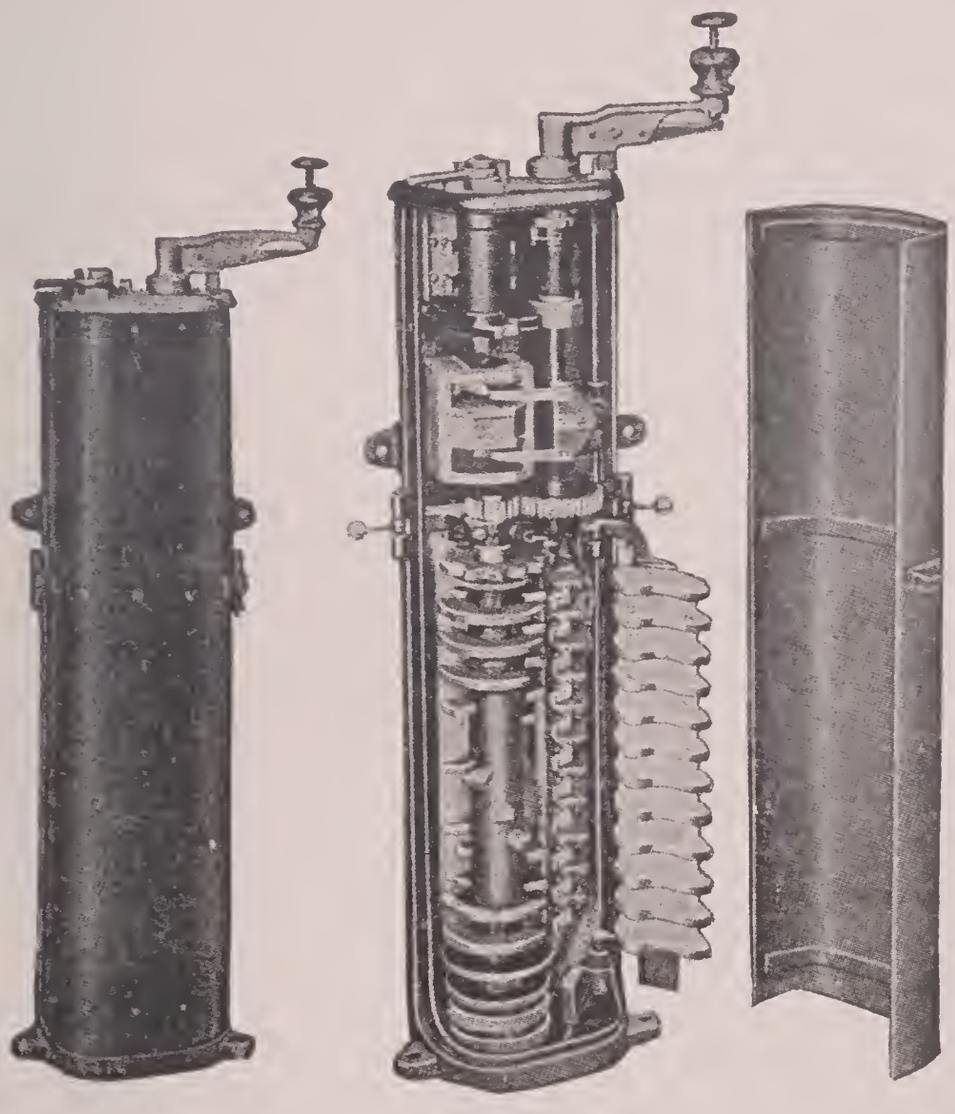


Fig. 378. Master Controller for Sprague-General Electric Control.

Each motor and trail car is equipped with train cable, consisting of nine or ten individually insulated conductors connected to corresponding contacts in coupler sockets located at each end of the car. This train cable is

connected identically on each motor car to the master controller fingers and the contactor and reverser operating coils, and is made continuous throughout the train by couplers between cars, connecting corresponding terminals in the coupler sockets.

All wires carrying current supplied directly from the master controller form the "control circuit"; those carrying current for the motors form the "motor" or "power circuit."

Inasmuch as the motor controller operating coils are connected to this control train line, it will be appreciated that energizing the proper wires by means of any master controller on the train will simultaneously operate corresponding contactors on all the motor cars, and simultaneously establish similar motor connections on all cars.

Advantages.

The Sprague-General Electric Type M Control permits a train of motor cars and trailers to be operated as a single unit from any master controller on the train. If desired, a master controller can be placed on each platform of trail cars, thereby providing for the operation of the train from any platform. With this arrangement, the motorman can be always at the head of the train, regardless of the combination of the cars.

The entire train, equipped with Type M Control, may thus be regarded as a unit; the motorman has the same control over a train that he would have over a single car with the ordinary cylinder controller.

Should the motorman remove his hand from the operating handle of the master controller, the current will

be immediately cut off from the entire train, thus diminishing the danger of accident in case the motorman should suddenly become incapacitated.

The system will operate at any line potential between 300 volts and 600 volts, and the action of all contactors is absolutely reliable and instantaneous.

On heavy equipments the effort of the motorman in operating the master controller is so much less than that required to handle a large cylindrical controller that he can give more attention to the air brakes and other parts of the equipment, especially in cases of emergency.

The approximate total weight per motor car of control equipments, exclusive of supports, is 2,500 pounds for 300 H. P. of motors.

The approximate weight of the apparatus for each trail car, which comprises train cable, coupler sockets and connection boxes, is 100 lbs.

In many cases it will be found advantageous to anticipate the future growth of an interurban road by equipping each motor car with Type M Control. In these cases it will be easy to change from single car to train service whenever warranted by traffic conditions.

The position of the handle on that master controller which the motorman is operating always indicates the position of motor control apparatus on all cars.

Contactors.

The contactors are the means of cutting in and out the various resistances, of making and breaking the main circuit between trolley and motors, and of changing from series to parallel connection.

Each contactor consists of a movable arm carrying a renewable copper tip which makes contact with a similar fixed tip, and a coil for actuating this arm when supplied with current from the master controller. The contactor is so designed that the motor circuit is closed

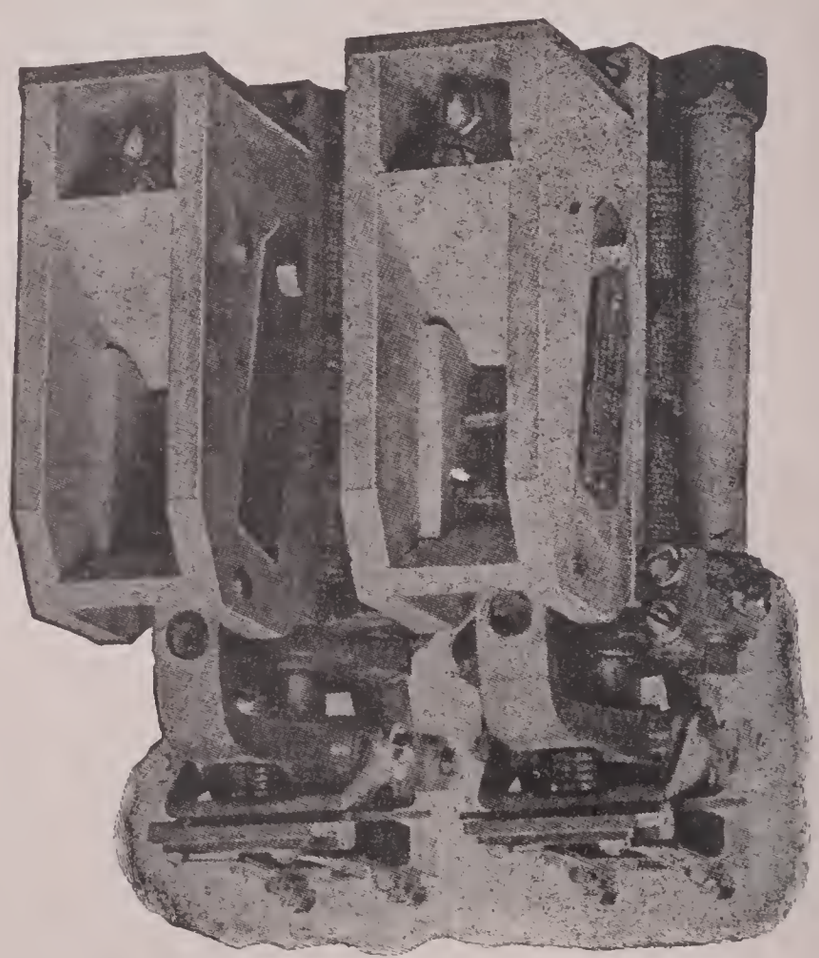


Fig. 379. Contactors with Interlocks.

only when current is flowing through its operating coil; and gravity, assisted by the spring action of the finger, causes the arm to drop and open the circuit immediately when the control circuit is interrupted. Each contactor has an effective and powerful magnetic blow-out, which

will disrupt the motor circuit under conditions far exceeding normal operation. In closing, the copper tips come together with a wiping action, which cleans and smooths their surfaces.

All contactors in an equipment are practically identical, and the few parts which are subject to burning and wear are so constructed as to be readily replaceable.

In order to save space and eliminate interconnections as much as possible, several contactors are mounted on the same base (Fig. 379). The contactors should preferably be located under the car, and boxes are therefore supplied which facilitate installation, protect the contactors from brake-shoe dust and other foreign material, and provide the necessary insulation. These boxes are built with perforated openings for ventilation, but shields are supplied for closing these perforations whenever desirable.

Reverser.

The general design of the reverser (Fig. 380) is somewhat similar to the ordinary cylindrical motor reversing switch with the addition of electro-magnets for throwing it to either forward or reverse position. In general construction, the operating coils are similar to those used on the contactors, but in order to secure absolute reliability of action in throwing, the coil is given full line potential. The reverser is provided with small fingers for handling control circuit connections, and when it throws, the operating coil is disconnected from ground and is placed in series with a set of contactor coils, thus cutting the operating current down to a safe running value. These coils are protected by a fuse, which will

immediately open the circuit if the reverser fails to throw. If the position of the reverser does not correspond to the direction of movement indicated by the reverse handle on the master controller, the motors on that car cannot take current. While the motors are taking current the operating coil is energized, and the electrical circuits are interlocked to prevent possibility of throwing.

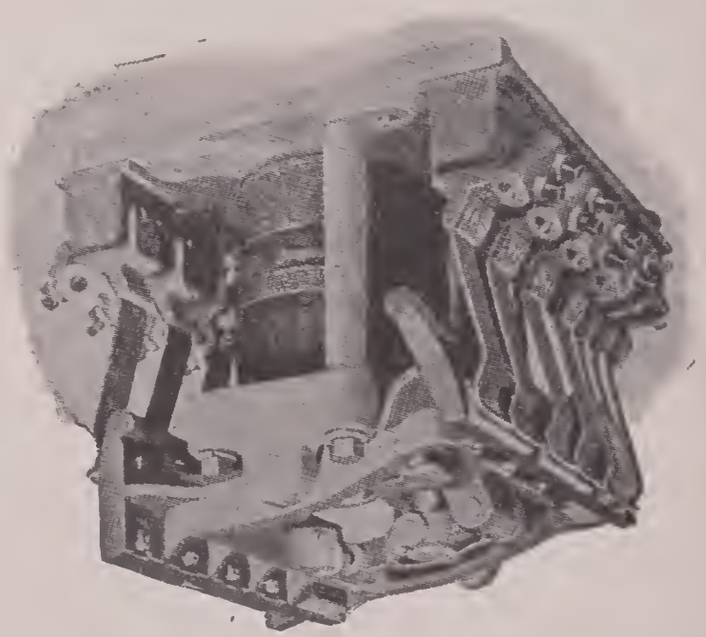


Fig. 380. Reverser on Motor Cars.

Master Controller.

The master controller (Fig. 378) is considerably smaller than the ordinary street car controller, but is similar in appearance and method of operation. Separate power and reverse handles are provided, as experience has led to the adoption of this arrangement in preference to providing for the movement of a single handle in opposite directions.

An automatic, safety, open-circuiting device is provided whereby, in case the motorman removes his hand from the master controller handle, the control circuit will be automatically opened by means of auxiliary contacts in the controller, which are operated by a spring when the button in the handle is released. This device is entirely separate and distinct in its action from that of the main cylinder. Moving the reverse handle either forward or backward makes connections for throwing the reverser to either forward or backward position. The handle can be removed only in the intermediate or off position. As the power handle is mechanically locked against movement when the reverse handle is removed, it is necessary for the motorman to carry only this handle when leaving the car.

When the master controller is thrown off, both line and ground connections are severed from the operating coils of important contactors, and none of the wires in the train cables are alive.

The current carried by the master controller is about 2.5 amperes for each equipment of 400 H. P. or less. This small current carrying capacity permits a compact construction, and the controller weighs only 130 lbs.

Master Controller Switch.

A small enclosed switch with magnetic blow-out is used to cut off current from each master controller, and is supplied with a small cartridge fuse enclosed in the same box. When this switch is open all current is cut off from that particular master controller which it protects.

Control Cable.

A special flexible cable, made up of different colored individually insulated conductors, is used for the train cable and, whenever possible, to make connections between the various pieces of control apparatus.

Connection Box.

Connection boxes are provided for connecting the control circuit cables at junction points without splicing, and small copper terminals are supplied for attaching to the ends of the individual conductors.

Control Couplers.

The master control cables of each car terminate in sockets and are interconnected by means of a short section of similar flexible cable fitted with plugs. Each socket contains a number of insulated, metallic contacts connected to the train wires, and the terminal plugs of the coupler contain corresponding contacts. The parts subject to wear are readily replaceable.

All coupler sockets are provided with spring catches which hold the plugs in contact under normal conditions, and permit them to automatically release in case two cars separate.

Control Cut-Out Switch.

This is a switch, usually nine-point, installed on each motor car and is used to disconnect the operating coils of the contactors and reverser from the train cable, and hence render them inoperative.

Control Fuses.

On each car several small enclosed fuses are placed in the control circuit at such points as to effectively protect the apparatus.

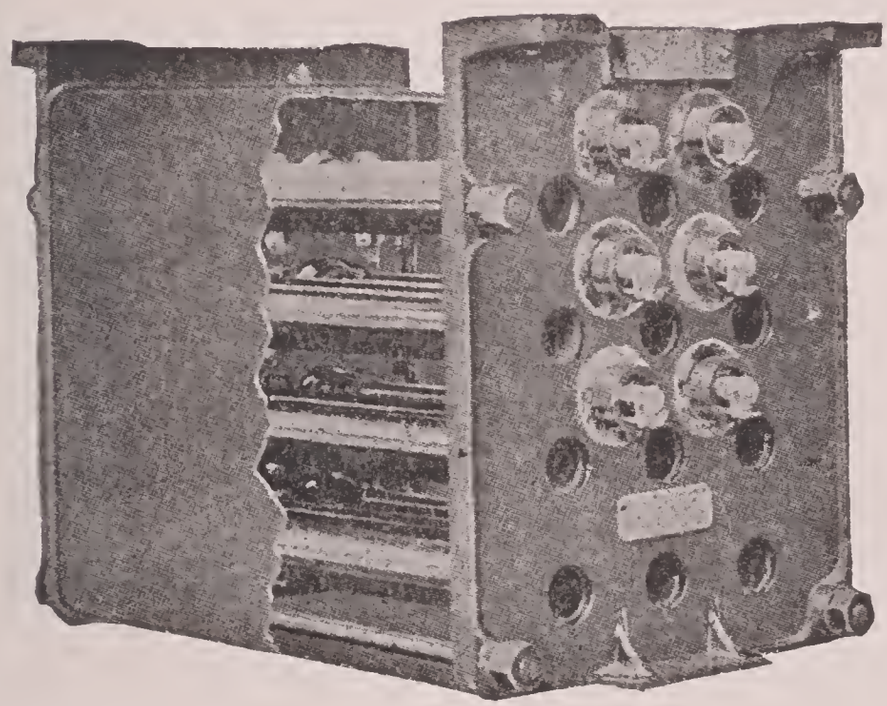


Fig. 381. Control Rheostat.

Control Rheostat.

While starting car, tubes of a high resistance rheostat are connected in series with the contactor coils to cut down the operating current to a value approximating that for the running positions of the controller. This rheostat is enclosed in a sheet iron case for protection. Fig. 381.

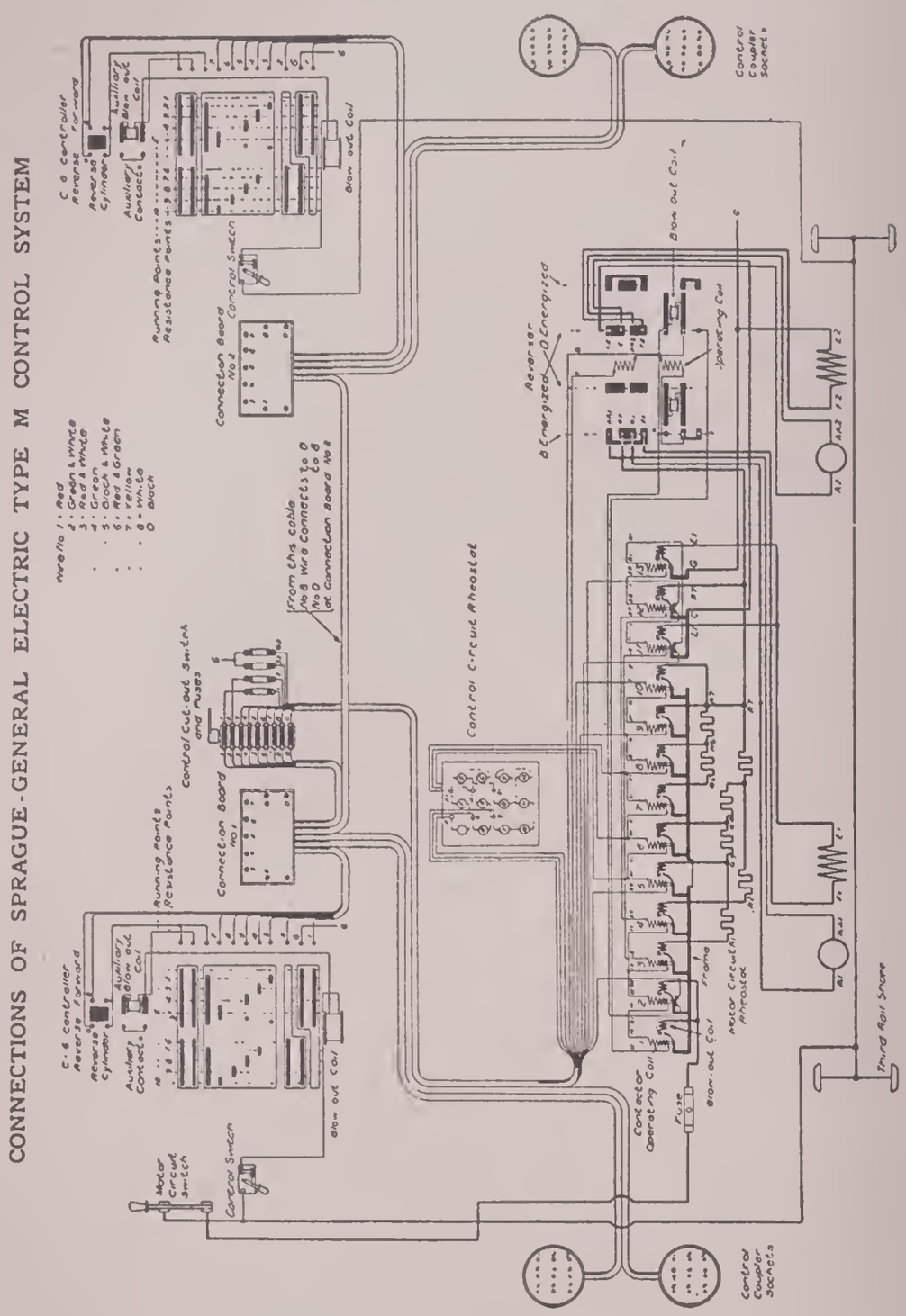

CONNECTIONS OF SPRAGUE-GENERAL ELECTRIC TYPE M CONTROL SYSTEM
C & C controller Reverse Forward
Reverse Cylinder
Auxiliary Contacts
Auxiliary Blow out Coil
Running Points
Resistance Points
Connection Board No 2
Control Switch
Blow out Coil
Wire No 1: Red
2: Green & White
3: Red & White
4: Green
5: Black & White
6: Red & Green
7: Yellow
8: White
0: Black
From the cable No 8 Wire connects to 8 No 0 at Connection Board No 2
Control Cut-Out Switch and Fuses
Connection Board No 1
Control Circuit Rheostat
Reverser
0 Energized
Operating Coil
Motor Circuit Switch
Contactor Operating Coil
Fuse
Motor Circuit Rheostat
Frame
Third Rail Shoe
Control Coupler Sockets

Fig. 382.

Circuits.

The motor circuit is local to each car, and on the first point the current on entering from the trolley or third rail shoe passes through the following pieces of apparatus in the order named: main switch and fuse, contactors, resistances, reverser, motors; thence to ground.

In the control circuit, the course of the current from trolley to ground is through the master controller switch and fuse, the master controller, connection box, to the cut-out switch. From the cut-out switch the current passes through the control cable to the operating coils of the reverser and contactors, and thence through fuses to ground.

Automatic Features.

The apparatus described is used with the standard equipment for hand control. If automatic features are desired they can be installed. See Lesson 36.

Wiring Diagram.

A diagram of the wiring of apparatus shown in Fig. 376 will be found in Fig. 382.

LESSON 36.

Automatic Acceleration.

In some systems of control the closing and opening of switches is in unison with the movement of the controller handle.

This has two disadvantages. In the first place the motorman by a too rapid movement of the handle gives the motor current too fast, which results in the car starting too fast, causing a waste of current and discomfort to passengers. Secondly, the motorman may through caution start train too slowly and thus spoil the schedule speed.

To remedy the first and most important, starting too fast, *controlled acceleration* was adopted. Devices called "motoneers," "auto motors," etc., were placed on controllers. All these are friction or rachet and pawl affairs which bind when handle is moved too fast, or which compel a stop at each controller point.

Some controllers, as the New York Central locomotives, have a friction clutch operated by the main current. When engineer moves controller handle too fast, too much current flows to motors. This excessive current sets the friction clutch so that handle can be moved no further till current falls to its proper value.

The New York Subway controllers (Fig. 383) have handle geared to the main cylinder but the motion is transmitted from handle to gears through a heavy spiral spring. The handle may be thrown all the way round,

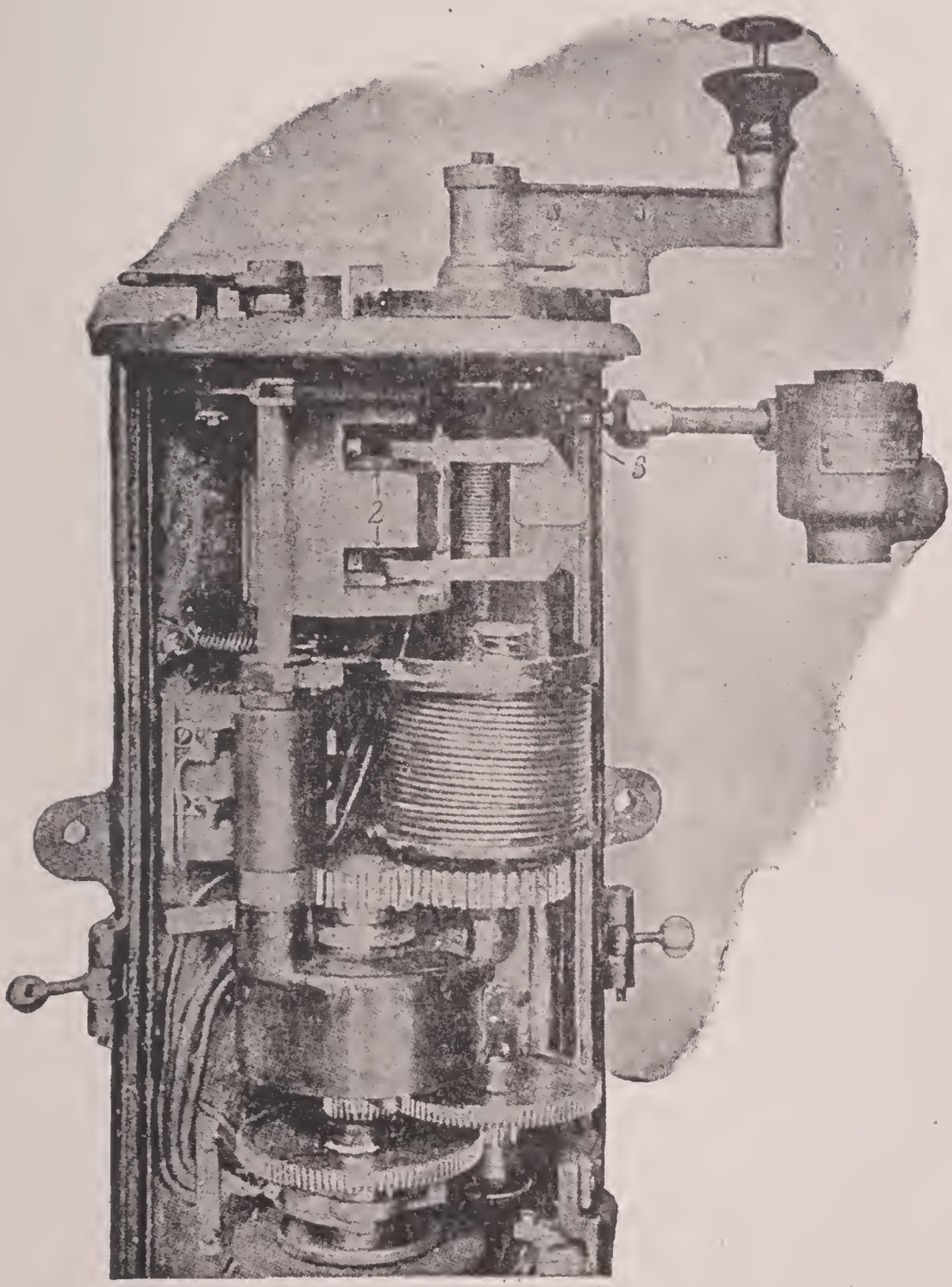


Fig. 383. Controller Used with New York Subway Equipments.

which winding the spring, causes it to turn the main cylinder. The speed of this main drum is regulated by a friction clutch operated by the current passing through motors.

At 1 in Fig. 383 is the button which must be held down at all times when motors are receiving power. Should it be allowed to rise it will allow the auxiliary contacts at 2 to make upper contact, thus cutting power off the motors while at same time through the medium of a pilot valve at 3 (hardly visible in figure) and a brake valve at 4, giving the emergency application of air brakes.

When handle is at "Off" the button may be let up without applying brakes.

The New York Central automatic acceleration is not an attachment to the controller, nor is it a controlled acceleration as in the Subway type. It is a true automatic acceleration and the whole system of control is built with that end in view.

The controller is shown in Fig. 493.

The controller when on second and fourth notch ahead or on second notch reverse, has two wires in circuit called the *pick up* and *hold up* wires. The duty of the pick up wire is to close contactors, the contactor is then held up by the hold up wire.

Fig. 384 shows how the automatic acceleration takes place.

The power circuit comes from the trolley connection through the resistances and through the coil of the relay R and thence to the motors. E is the contact which the relay opens and closes. The coil which operates the contactor is marked M. The rod which pulls up the jaw of the contactors passes up through the contactor

coil M and carries four plates A, B, C and D. A series of contacts as shown by the little black circles are arranged as in the diagram.

The two control wires 1 and 2, are connected to trolley and energized through the controller. W1 is the *pick up* and W2 is the *hold up* wire.

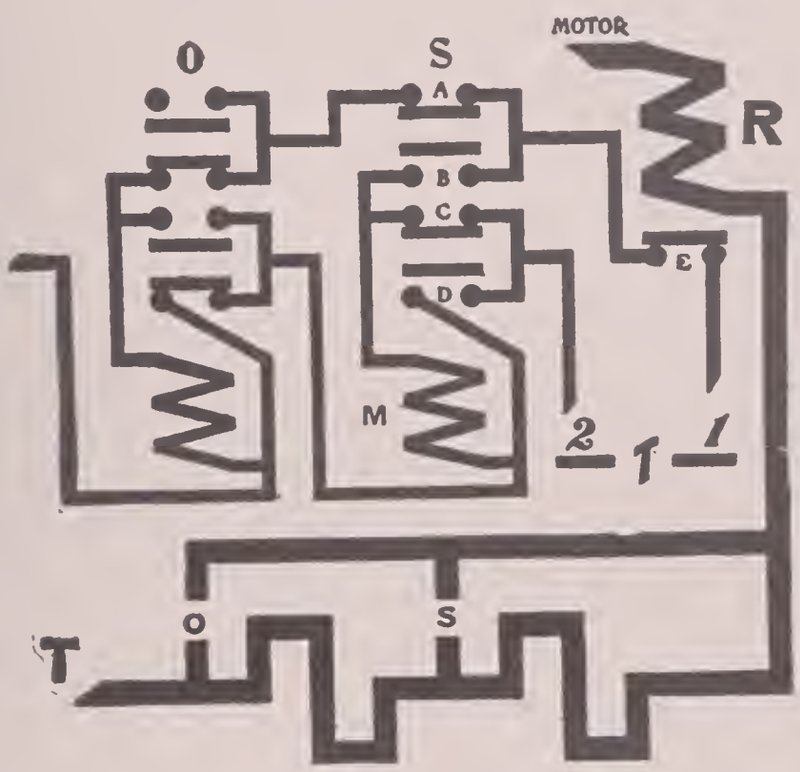


Fig. 384. Diagram of Wiring and Interlocks for Automatic Acceleration.

The contactor marked S is shut and the one marked O is open.

By reference to O you will understand how S was closed, in the following manner.

Current comes through W1 and passes through the B contacts down through the coil M and along W2 to the next contactor.

The contactor now closes and a reference to S will show how it remains closed.

The closing pushed the plates up and out of contact at B and D; and into contact with A and C. The current from W1 now passes through the A contacts and on to the next contactor, where it "picks it up." The coil M is now in the W2 circuit by means of the C contacts and is "held up."

The circuit of W1 is always closed either through the A or the B contacts of some contactor. When passing through the A contacts of a shut contactor it simply passes on to the next. When passing through the B contacts it is "picking up" the contactor for it goes through the coil M in passing on to the next contactor.

The circuit of W2 is always closed either through the C or D contacts. When passing through the D contacts of an open contactor the current passes on to the next contactor. When passing through the C contacts of a closed contactor it is "holding up" the contactor for it passes through the magnet coil M.

If there were no relay R all the contactors would close practically at once. When a contactor shuts like S there is a sudden increase of the current to the motors and the contact E is pulled open by the relay R. The circuit of W1 is interrupted and hence contactor O does not close.

When the motor speeds up the current is reduced and E closes when O closes at once, for the current flows again in W1 and the magnet is energized.

So W1 picks up the contactors in succession as allowed to do so by the contacts E; and W2 holds up the contactors when closed by W1 and passes through the contactors, which are open, without affecting them.

The contactors are operated from a controller with four notches forward and two backward. There is no reverse lever.

The controller handle will stay at the off position, but at no other unless held there, as a spring acts against the engineer whether handle is moved forward or backward.

This is a safety device which cuts off the power if the engineer becomes disabled or careless. There is a button on the handle which when the handle is in the off position is idle, but to start the train in order to get power to the motors it must be pushed down and kept down as the handle is moved around.

When the handle is returned to the off position in making an ordinary stop this button is released but does nothing except cut off power from the controller, which has already cut power off from the motors.

Should this button be allowed to rise when handle is in any *on* notch the emergency brake will be set.

The notches of the controller are named:

FORWARD.

1. Switching.
2. Series.
3. Lap.
4. Parallel.

REVERSE.

1. Switching.
2. Series.

When the controller is moved to N. 1 Forward the reverser is thrown to the forward running position, and contactors are closed placing the motors in series with all resistance in.

This gives a slow speed for moving about the yards, switching and the like. It is also your first speed in starting a train. This speed must not be used very long at one time as the resistances will heat. The proper management of the train is to put on the switching speed and then coast; or if that won't take you then throw to the second notch, shut off and coast.

Notch 2: Five contactors are now automatically energized in succession, separated by a sufficient time to allow the train to accelerate at 1¼ M. P. H. P. S. This time interval between the contactor closings is regulated by the throttle relay.

When these operations are finished the motors are in full series without resistance.

In moving from N 2 to N 3 there is a *bridge* connection thrown across and the contactors put all the resistance in with the two motors in parallel.

Notch 3 is a temporary notch and the handle is at once moved to N 4 when the resistances are automatically cut out at such intervals as will accelerate the train at 1¼ M. P. H. P. S.

This finally places the motors in parallel without resistance.

If the engineer wishes the handle can be thrown *at once* to N 4 and the train will move forward at 1¼ miles acceleration. The contactors make all the above mentioned changes automatically, so that 40 seconds after the start the train is moving at the rate of 50 M. P. H.

In fact to get the quickest and smoothest start this is the best way to handle the controller.

LESSON 37.

Single-Phase Compensated Motor Equipment.

WITH SERIES PARALLEL CONTROL.

Electric railway motors in general use throughout the world are operated, as is well known, by direct current with a trolley voltage of about 600 volts. For heavy service and extended systems the cost of copper required at 600 volts becomes a serious item, and for some time there has been felt the need of a higher trolley voltage. The use of alternating current for the trolley would admit of a higher voltage than is possible with direct current, as the voltage could be reduced by a transformer on the car to the potential required by the motors. The development of large power stations and transmission systems has been principally with alternating current, requiring rotary converters, or other commutating devices for changing the alternating current into direct current suitable for the operation of electric railways. Obviously there would be a great advantage in a railway motor equipment that could be operated from an alternating current high voltage trolley and without the necessity of intermediate commutating devices. Such an alternating current equipment would offer a further advantage if it could be operated both on alternating extensions of existing systems and also on the direct current trolley where the latter is already installed.

For several years engineers have been working on this problem, and have developed a type of alternating current equipment suitable for general traction work.

The activity displayed in Europe in adapting the three-phase alternating current motor to the conditions of railway service has never been fully shared by American engineers, due to the limitations of the multiphase* induction motor. The development of the single-phase compensated motor (with a commutator) with its inherent fitness for traction work has attracted very wide attention among railway interests, and work of a practical nature has been actively pushed on both sides of the Atlantic. Considerable importance is therefore attached to the operation in regular service of single-phase alternating current motors. Its commercial possibilities are largely due to the fact that the motors operate with alternating current power outside the city limits and with direct current power inside the city limits.

Alternating Current Motor.

The alternating current motor, Fig. 385 and Fig. 386, is of the "compensated" type, so named on account of the character of the field winding, which fully neutralizes or compensates for the armature reaction. Both the compensated motors and control are adapted for operation on the 2,000 volt alternating current trolley between cities and the standard 600 volt direct current trolley in cities. This ability of the compensated motor equipments to run over tracks equipped with either alternating current or

*Another word for polyphase.

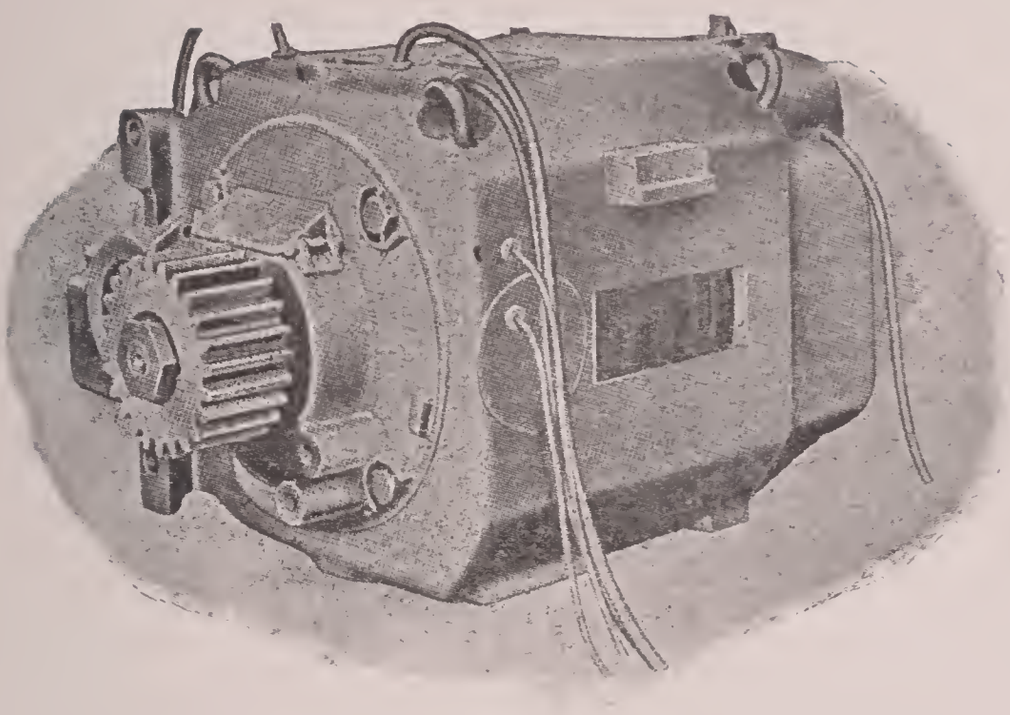


Fig. 385. 75 H. P. Series Compensated Motor. Pinion End.

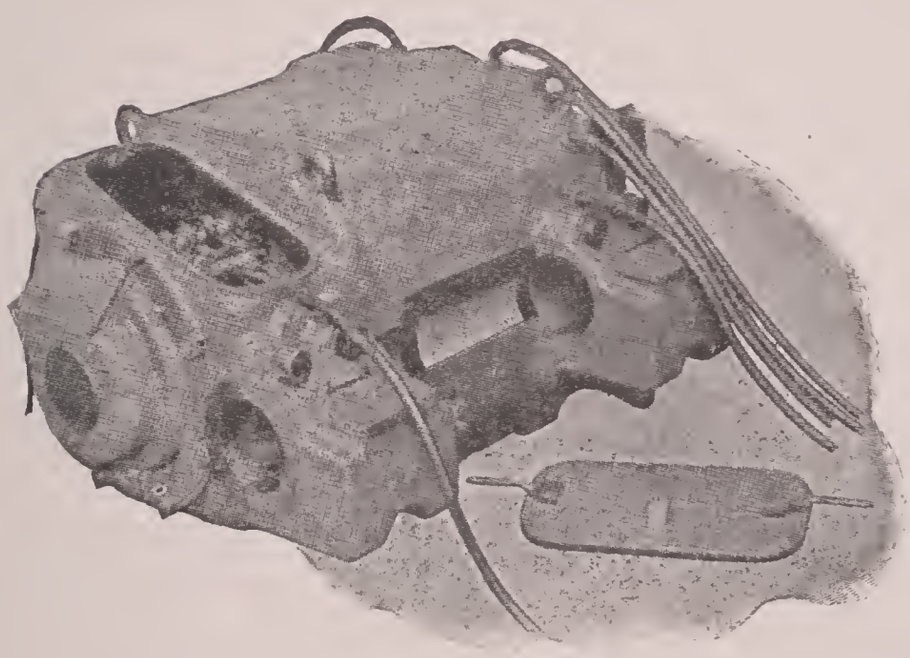


Fig. 386. Car Axle Side of Motor in Fig. 385.

direct current trolley makes their field of application very broad, as the cars can secure all the benefit of running over existing city tracks without in any way sacrificing their running qualities upon suburban sections equipped with alternating current trolley.

The alternating current motor, with its inherent advantages of high voltage distribution, is eminently adapted to replace the steam locomotive on either high speed passenger or heavy freight haulage work; and as the compensated type of motor is perfectly adapted to operate on both alternating current and direct current trolley, the alternating current motors must be considered a large factor in future suburban railway systems. The compensated motor is essentially a variable speed motor, differing in this respect from the multiphase induction motor, whose constant speed characteristics proved so serious a handicap to its successful adoption in railway work. The characteristics of the compensated motor are very similar to that of the direct current series motor, while its commutating qualities and method of control prove equally satisfactory.

The truck with two 75 H. P. motors is shown in Fig. 387.

The A. C. compensated motor consists of an annular laminated iron field with a winding similar to that of an induction motor, and an armature provided with a commutator similar in general mechanical construction to a direct current railway motor armature. These motors are wound for 200 volts, are permanently connected two in series, and are fed from the 400 volt secondary of an 80 k. w. air-blast step-down transformer carried on the car. The distributed character of the field winding

fully compensates for the armature reaction, so that power factors are relatively high throughout the range of operation. This type of motor is so designed that

Fig. 387. Truck with 150 H. P. of Compensated Motors.

at the free running speed of the car, which is the condition most frequently met with in suburban work, the power factor and efficiency are nearly at their maximum

values. A high power factor is desirable, as it reduces the capacity and cost of the generating and distributing systems, and more especially effects a material improvement in the regulation of the alternating current generators. Unlike a direct current system which has a practically constant potential at the sub-station bus-bars, irrespective of the load, the drop in an alternating current railway system increases with the load. It is desirable therefore to maintain as good a power factor as is consistent with good motor design, in order to limit the total drop of the system to a reasonable amount.

The characteristics for alternating current running are equal to direct current running in meeting the requirements of railway work. Unlike the multi-phase induction motor with its practically constant speed characteristic, the compensated alternating current motor varies its speed with the load, and is thus better adapted to operate trains over an irregular profile. The commutation of the compensated motor is equally satisfactory when running on alternating current or direct current, and this good commutation is secured by careful electrical and mechanical design without resorting to high resistance leads or other expedients liable to give trouble in case of sustained heavy overloads.

Alternating Current Equipment Adapted for Direct Current.

Our city railway systems have so expanded and cover such a large territory as to make it very objectionable, both on the score of first cost and complication, to install a separate alternating current trolley at reduced po-

tential in order that cars equipped with alternating current motors may benefit from running over city streets at terminals and en route. There is a comparatively small additional expense required to adapt alternating current equipments to run on either alternating current

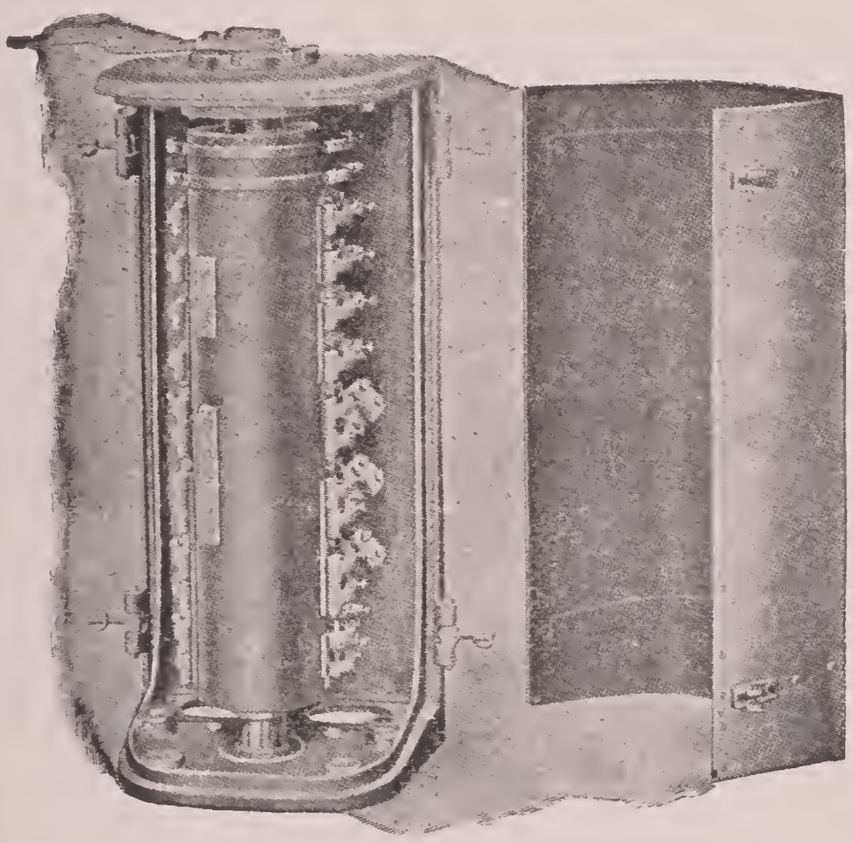
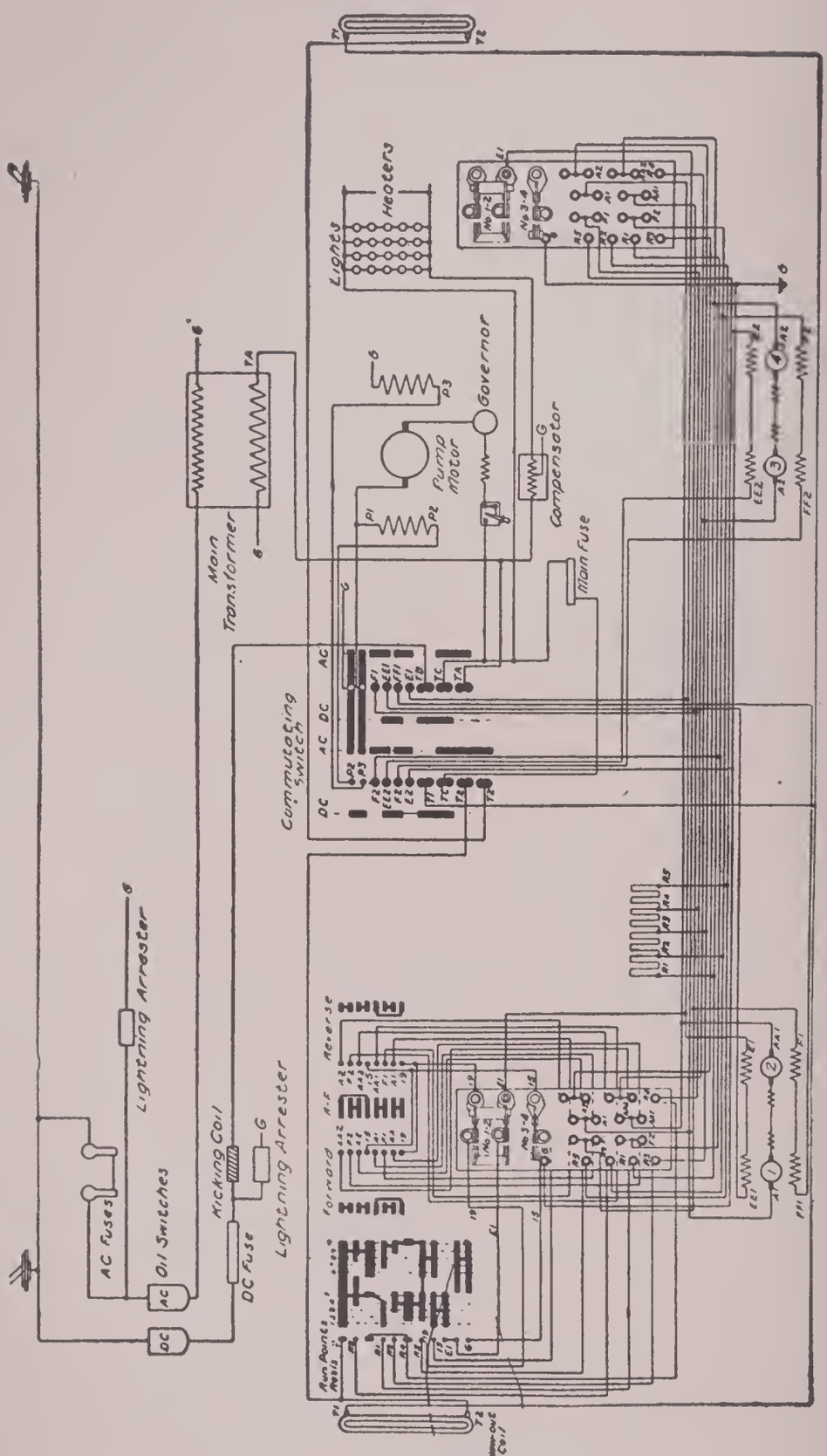


Fig. 388. Commutating Switch.

or direct current. This is accomplished with the use of a standard K direct current series parallel controller used in connection with a commutating switch, Fig. 388, to change field connections, cut out step-down transformer, change line fuses, etc. The time required to operate the commutating switch is but a few seconds. The scheme of connections for the complete car wiring is shown in Fig. 389.



CAR WIRING FOR ALTERNATING AND DIRECT CURRENT OPERATION

Fig. 389.

The commutating switch is interlocked with two main oil switches, Fig. 390, one being in the high tension alternating current and the other being in the direct current circuit; this interlocking being so arranged that only one switch can be closed at a time, and the commutating switch can only be thrown when the oil switches are in the off position. Owing to the fact that the alternating current trolley construction is off center, while the standard city and suburban trolleys are directly overhead, it has been necessary to provide double

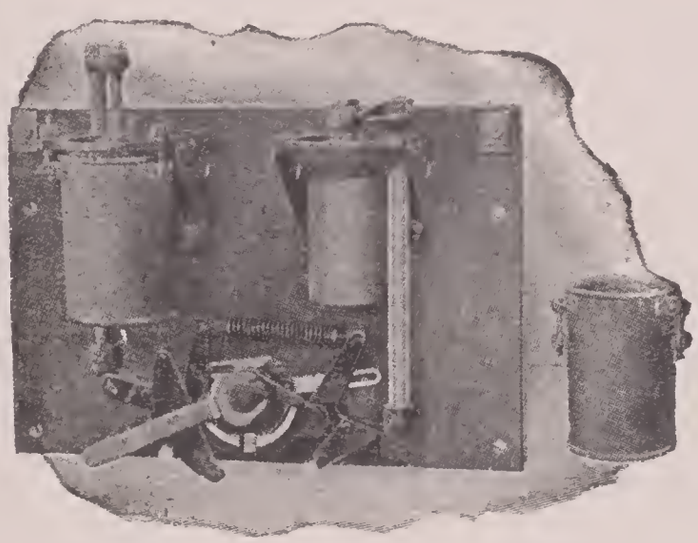


Fig. 390. Oil Switch. Interlocked with Commutating Switch.

sets of trolleys, one for alternating current and the other for direct current, hence the necessity for interlocking the oil switches and commutating switch to prevent trouble should both trolley poles accidentally be up at the same time. Where center wire construction is used on both the city and suburban sections, the alternating current and direct current trolley wires may be overlapped for a short distance to facilitate changing from one trolley to the other.

Sub-Station.

Owing to the fact that 25 cycle, three-phase generators are almost universally used to supply rotary converters in existing interurban railway systems, both the design of the compensated motor and the alternating current distributing system is adapted to operate from existing 25 cycle generating stations. As the alternating current motor is single-phase, a single-phase generating and distributing system commends itself on account of its simplicity. The step-down transformers may be tied together on the low tension side through the trolley with consequent reduction in amount of copper required. Each sub-station acts as a reserve to the adjacent one, and a transformer may be cut out without shutting down a trolley section.

Trolley.

The form of alternating current trolley used is well adapted to the requirements of steam roads where the local service is taken care of electrically and through passenger traffic and freight handled by steam locomotives, pending a complete change to electrical operation. The trolley wire and insulators being off center of track are not exposed to the gases of the locomotive exhaust with consequent deterioration, and furthermore a catenary* construction placed off center can be hung much lower than a standard center wire without interfering with brakemen on freight cars. A low running trolley at the side of the car is also preferable in main line

*See Lesson 33.

operation, as it conforms better to the clearance diagram of such roads without calling for too great a change in height of the trolley wheel or bow.

Control.

With equipments operating with both alternating current and direct current power, it is preferable to utilize the standard series-parallel controller in order to minimize the weight of controlling apparatus. Such a method of operation will not give quite so high efficiency when accelerating with alternating current as could be obtained with potential control. This difference in efficiency, however, is very small, partly due to the infrequency of stops occurring upon those sections of the road equipped with alternating current trolley, but principally due to the flexible character of the alternating current motor which gives a high efficiency of acceleration with series-parallel control.

With modern suburban cars, especially those equipped with train control, air brakes, air compressors, etc., there is some difficulty in suitably locating the power apparatus, even when equipped for direct current running only. With cars equipped for both alternating current and direct current running, using series-parallel controller, there will be required but slightly more space and weight than for direct current running only. Should, however, advantage be taken of the slightly better efficiency of alternating current potential control, such cars must be operated by alternating current upon suburban and city sections with the resulting disadvantages, or the installation of two separate controlling systems must be consid-

ered, necessitating a considerable increase in weight and difficulty in providing room for the necessary apparatus.

The efficiency of the potential control is not over 2 or 3 per cent higher than that of the series-parallel control, but the use of the latter, permitting operation with both alternating current and direct current, secured the advantage of the higher efficiency of the motors when running with direct current over city streets.

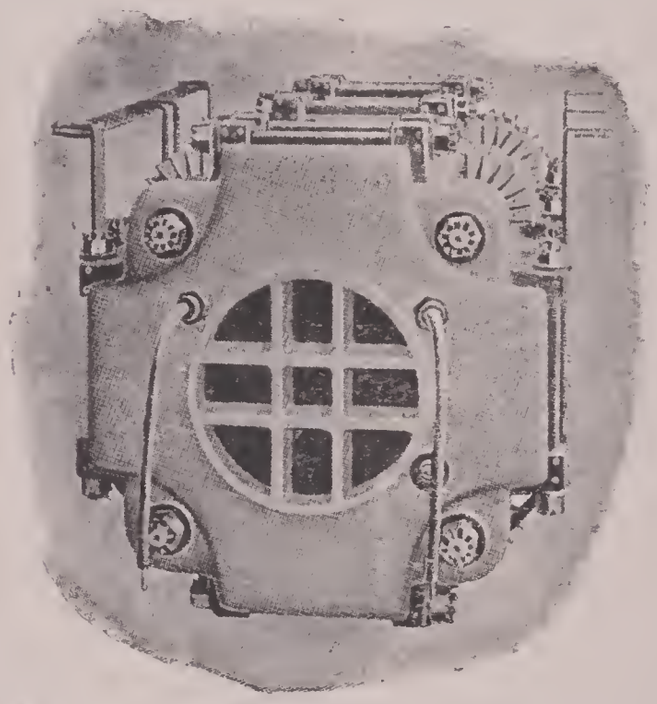


Fig. 391. Air Cooled Step-Down Transformed.

For locomotive or other service where no necessity exists for operation over city direct current systems, the potential method of control does offer advantages sufficiently great to warrant its adoption.

The 80 k. w. step-down transformer, Fig. 391, is air cooled, forced draught being obtained by the motion of the car itself. The transformer is suspended below the

car floor, and all primary leading-in wires are carried in brass tubing which is grounded. Car lighting and heating are effected from the direct current trolley in the standard manner, and from the alternating current trolley from the secondary of the transformer. Trolley poles and wheels are of standard design, the alternating

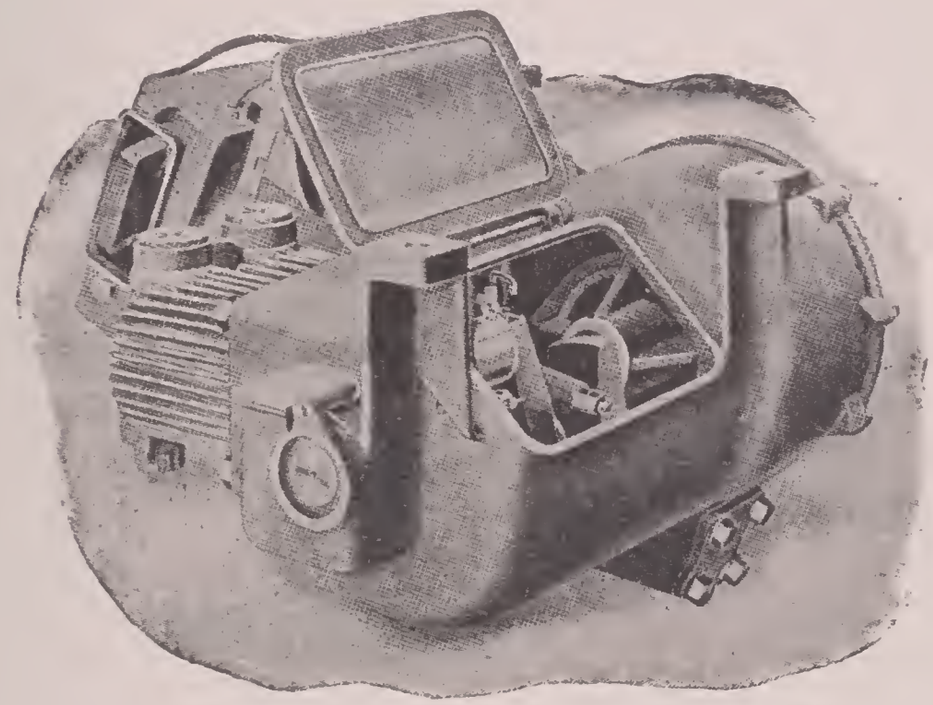


Fig. 392. Air Compressor with Compensated Motor.

current trolley pole being somewhat shorter, as this wire is lower than the direct current trolley. The base of the alternating current trolley is treated with vacuum compound, and further insulated from the car body by composition insulators. The air compressor for the brakes and whistle is operated by a compensated motor which operates from both alternating current and direct current circuits. Fig. 392.

Comparative Operation on Alternating and Direct Current.

It is instructive to compare the performance of the compensated motor equipment when operated with alternating current and direct current.

Comparative Alternating Current and Direct Current Runs.

	D. C.	A. C.
Length of run	1.6 miles	1.6 miles
Weight of car	31.55 tons	31.55 tons
Time	180 seconds	180 seconds
Average current on	229 amperes	346 amperes
Average voltage	606	425
*Kilo-volt-amperes full speed on level	98	110
Volt-ampere-hours per ton-mile of given run	86.3	125.5
Average speed	32 m. p. h.	32 m. p. h.
Schedule speed including 15-second stops	29.5	29.5

The lower volt-ampere-hours per ton-mile of the direct current run are partly due to the better efficiency and power factor of the compensated motor when run with direct current, and partly due to the somewhat higher rate of acceleration, permitting some coasting and resulting in a more efficient speed-time curve. The difference in kilo-volt-amperes alternating current and direct current depends upon the length of the run, and

*Another name for kilowatts.

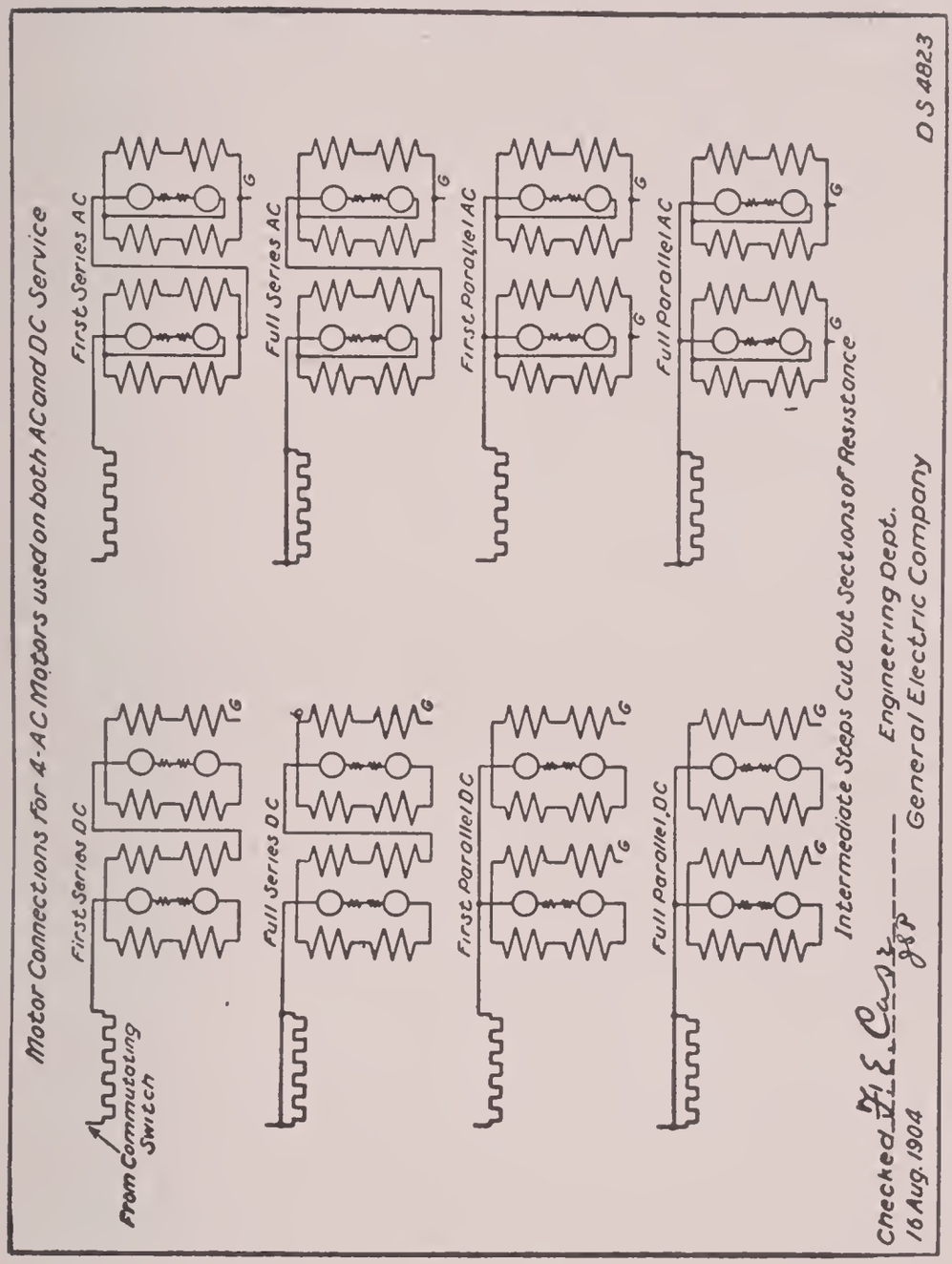


Fig. 393. Arrangement of Fields and Armatures when Running D. C. and A. C.

the values approach each other more nearly the longer the run. It will be noted that the compensated motors run the car at practically the same speed with 200 volts per motor alternating current and 300 volts direct current. This uniform speed is obtained by series paralleling the fields as shown in diagram of connections. Fig. 393.

Commercial Possibilities.

The compensated motor, having demonstrated its fitness for traction work, opens up possibilities in converting main line steam roads which were closed to the direct current motor and the rotary converter combination on the score of first cost of operation. The form of trolley suspension used is capable of being operated at more than 2,000 volts, which together with its mechanical construction, helps to solve the question of current collection of heavy units at high speeds. The commercial development of the alternating current motor is opportune, as steam railway managements throughout the country are displaying great activity in acquiring competing electric roads and in electrically equipping portions of their systems now operating at a loss with steam locomotives. The compensated motor is well qualified to meet the conditions of local passenger service, and holds out the promise of much larger possibilities in the way of direct competition with the steam locomotive in main line work.

Fig. 394 shows car equipped with above described apparatus.

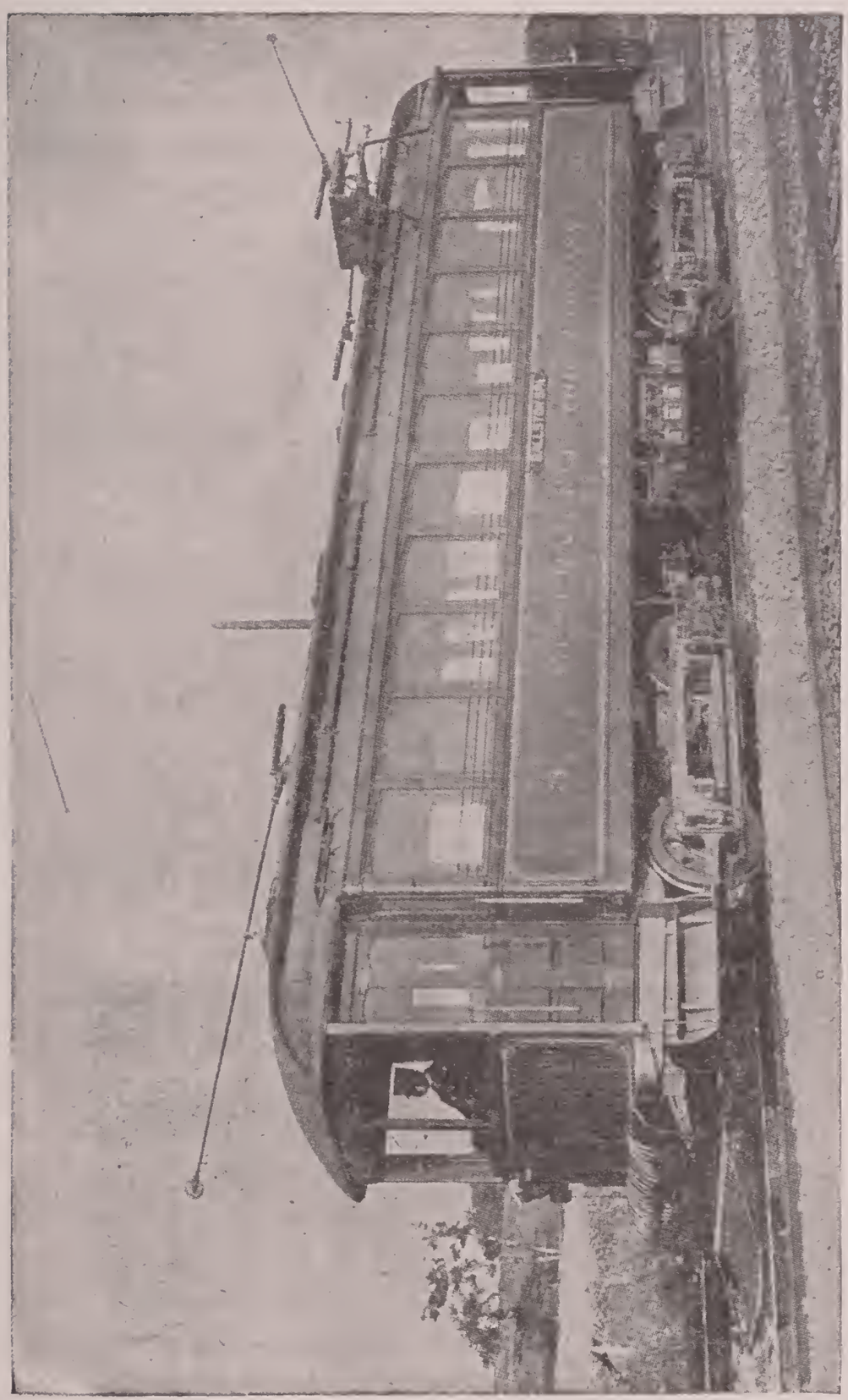
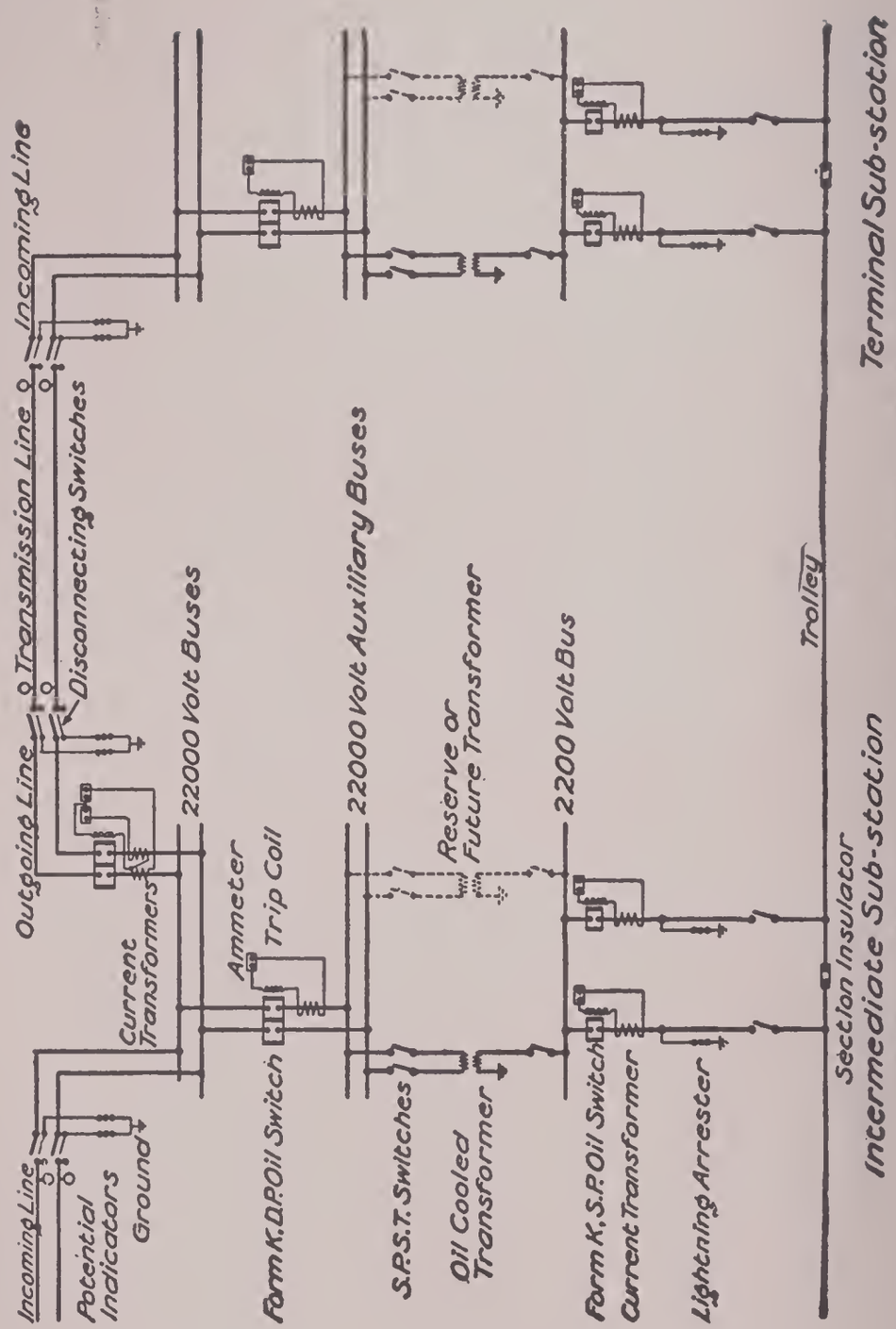
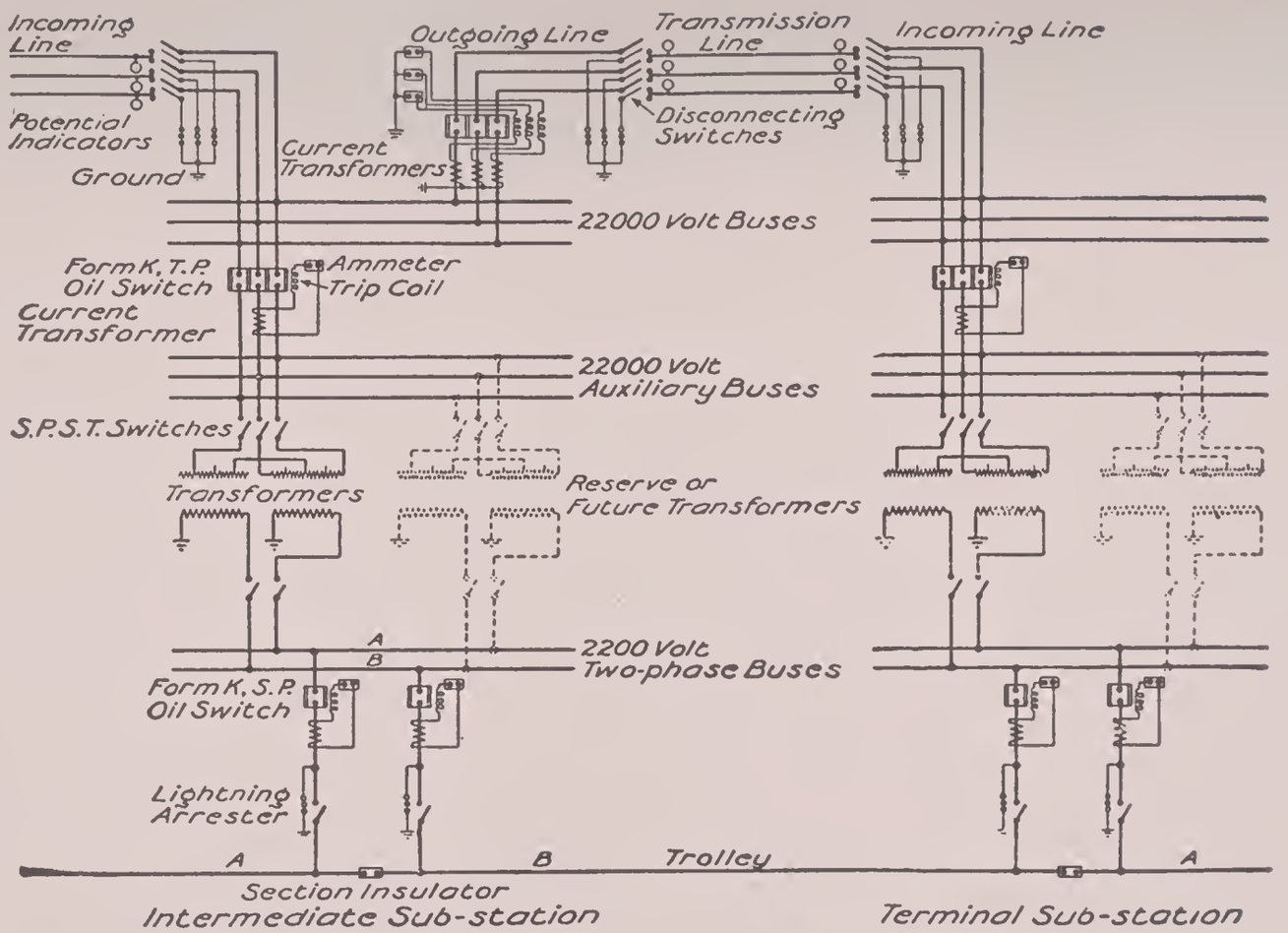


Fig. 394. Car Equipped with Compensated Motors for Operation on A. C. or D. C.



DISTRIBUTION SYSTEM, FOR SINGLE-PHASE RAILWAY, SINGLE-PHASE TRANSMISSION

Fig. 395.



DISTRIBUTION SYSTEM FOR SINGLE-PHASE RAILWAY, THREE-PHASE TRANSMISSION, SINGLE TRACK

Fig. 396.

The connections between the transmission line and the trolley wire are shown in Fig. 395, where single-phase current is used throughout. With a three-phase transmission line, Fig. 396 shows the connections.

LESSON 38.

Sprague-General Electric Multiple Unit Control for Alternating and Direct Current Operation.

Since the first single-phase equipment was placed in commercial operation, the advantages gained by the adoption of such a system for certain phases of railway work have become more generally recognized. In consequence its field has enlarged, and now there is a demand for such cars equipped with multiple-unit control. The General Electric Company has designed and developed suitable apparatus capable of controlling both single cars and trains equipped with single-phase motors when operating on lines supplied wholly with alternating current, or with alternating current on one portion of the line and direct current on another.

In general the alternating direct current multiple-unit system of control is similar to the well-known Sprague-General Electric type M control for direct current operation. The changes necessary in the type M control to adapt this apparatus for alternating current operation, are of a simple nature, and in this later development all the essential features and advantages of the older type of construction are maintained.

The multiple-unit system may conveniently be divided into two parts, the first consisting of a motor controller, composed of a number of electrically operated switches

called "contactors," which take the place of the ordinary cylinder controller, and may be considered as a more refined development of such, designed to handle currents of too large a magnitude to be dealt with by the ordinary controller. This apparatus is usually installed underneath the car.

The second part comprises a "master controller," the function of which is to operate the contactors; and a multiple cable, which extends the length of the train, and is provided with couplers between cars.

The train line apparatus, such as connection boxes, couplers, cut-out switches and cables, are identical with those used on standard type M equipments for direct current operation.

To adapt such a system for both alternating and direct current operation changes are made in the circuits of the contactor coils when the car passes from an alternating to a direct current section, and vice versa; the motor fields are also connected in series for direct current operation, and in parallel for alternating current. These changes are made as the car passes the short dead section separating the alternating and direct current portion of the trolley line, and at the same time either the resistance or compensator leads are put in circuit, as required.

For alternating current operation "Potential Control" is used; that is, acceleration is obtained by increasing the potential at the motor terminals by connecting compensator taps of successively increasing voltage to the motors in proper sequence, corresponding to the resistance steps of the direct-current equipment.

When the cars are to run on both alternating and

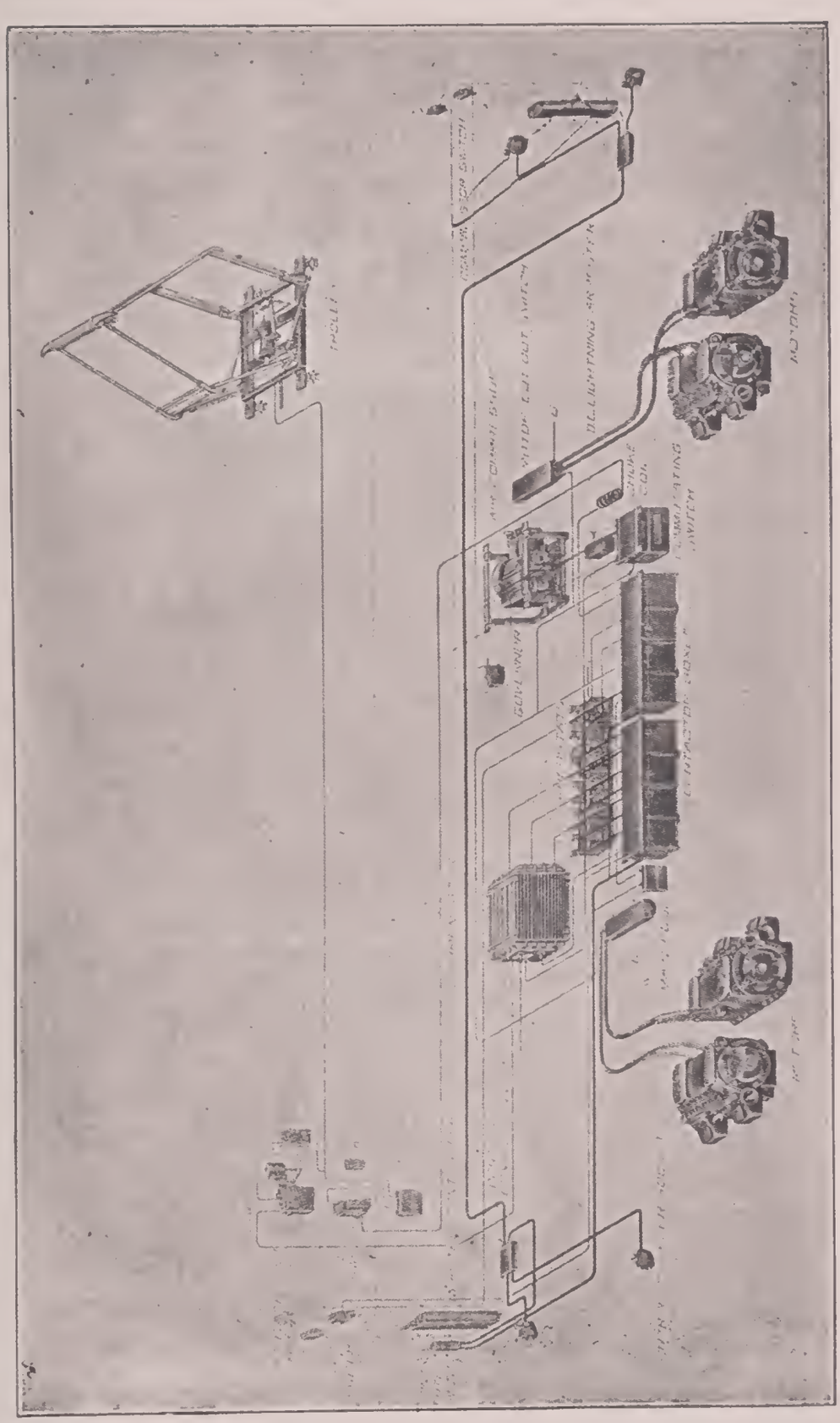


Fig. 397. Arrangement of Sprague-General Electric A. C. and D. C. Control on Car.

direct current lines, a special switch is supplied to make all the necessary changes in the circuits, and suitable cast grid rheostats are provided for giving the desired direct current acceleration which is obtained by cutting out resistance from the motor circuit step by step, in an exactly similar manner to that employed on ordinary direct current equipments.

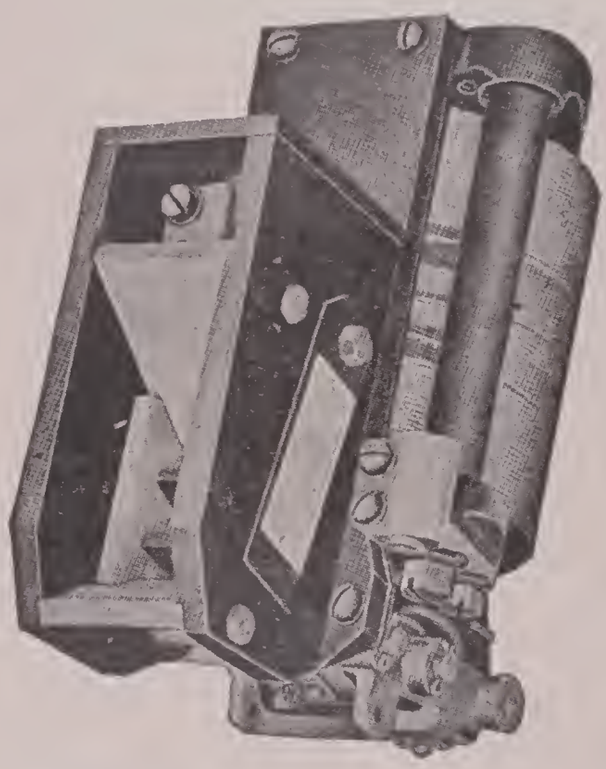


Fig. 398. Direct Current Contactor.

List of Apparatus.

The apparatus for each alternating-direct current car equipment consists essentially of:

Master controllers, Fig. 378.

Train cable and couplers, Fig. 397.

Contactors, Figs. 398 and 399.

Compensator, Fig. 400.
Set of rheostats.
Commutating switch, Fig. 388.
Trolleys, Fig. 397.
Motor cut-out switches, and
The necessary protecting devices.

The master controller and contactors are same as type M equipment.

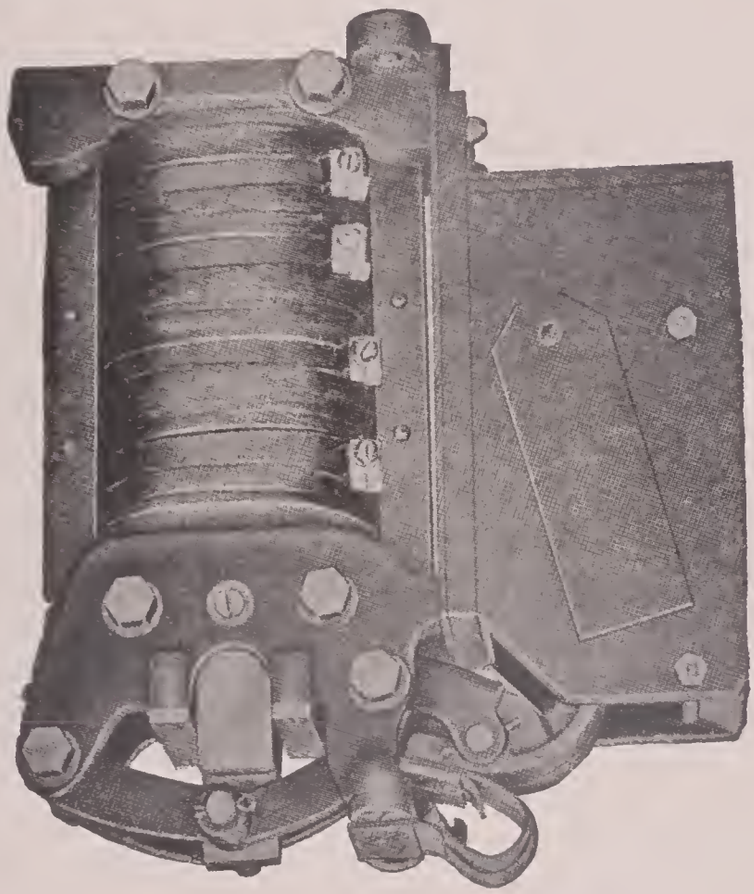


Fig. 399. Alternating Current Contactor.

Compensator.

The compensator, Fig. 400, which reduces the trolley potential to the proper voltage required for the motor, is of the oil-cooled type, suitably designed for suspend-

ing underneath the car body. It consists of a specially designed transformer structure entirely enclosed in a corrugated iron casing. The end castings are provided with stuffing boxes to prevent any leakage of oil where the taps enter. The coils of the compensators are specially well insulated to withstand the vibration to which such equipments are subjected. Taps giving various voltages are provided for controlling the speed of the motors.

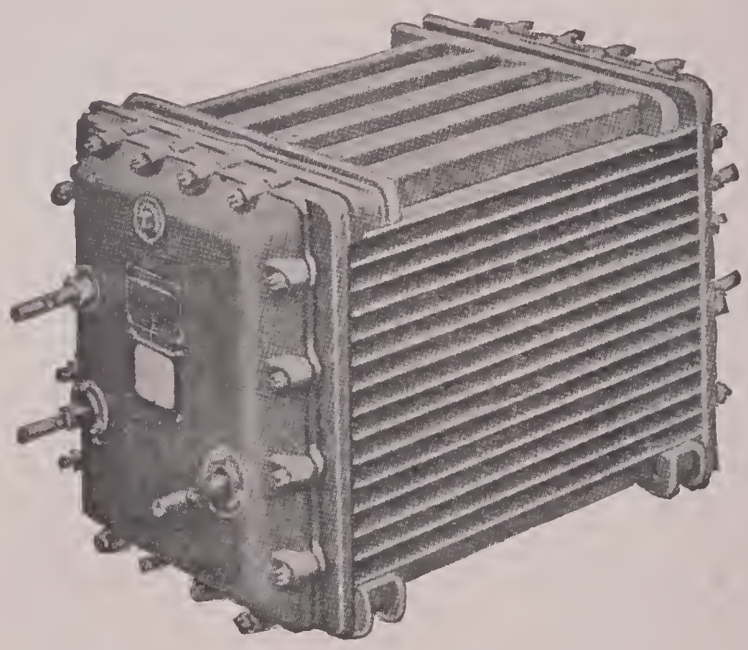


Fig. 400. Compensator.

Rheostats.

The rheostats are of the standard cast grid type, and are exactly similar in all respects to those used on the ordinary street car equipment.

Commutating Switch.

The commutating switch, Fig. 388, is used to make all the necessary changes in the circuits when the car passes from an alternating to a direct current section of the line, or vice versa. All such changes are accomplished by one operation.

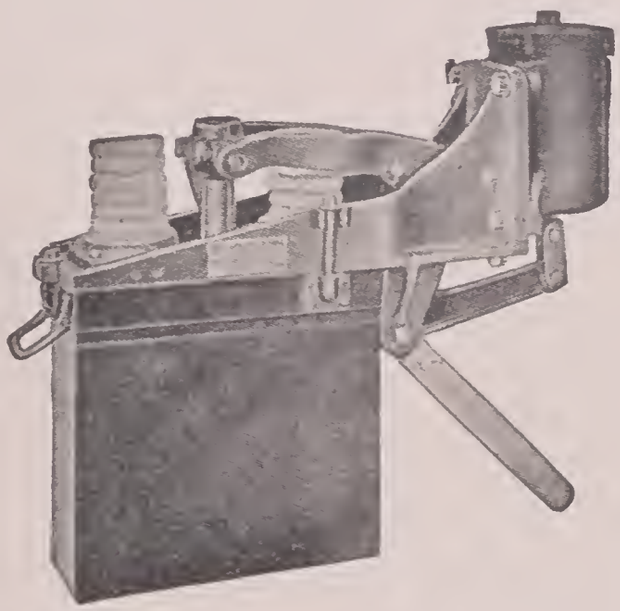


Fig. 401. Oil Switch for A. C. with Low Voltage Release.

Current Collectors.

The current may be collected by means of standard trolley wheels, poles and bases applicable for high speeds, or, when desired a sliding or rolling contact collector of the pantograph or bow type, such as has been used in Germany for a number of years, may be employed.

Insulation from the roof of the car is obtained by specially treated hard wood planking mounted on high tension insulators.

Protective Devices.

The oil switch, Fig. 401, in the high tension circuit is electrically operated and held closed by a coil energized from a small auxiliary transformer. This switch is protected by an expulsion fuse, Fig. 402. The main direct current switch, Fig. 403, has the same characteristics

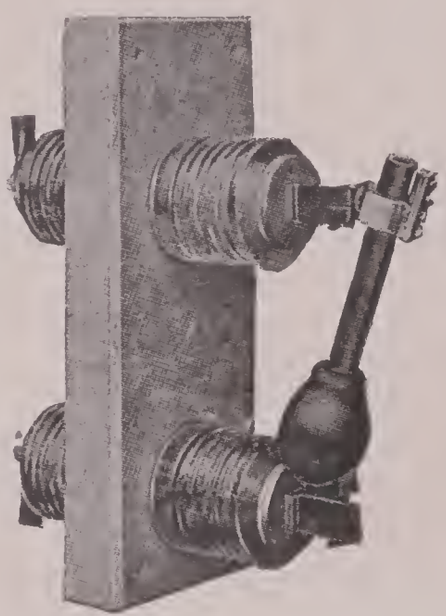


Fig. 402. Expulsion Fuse Rated at 30 Amperes with 6,600 Volts A. C.

as the oil switch but is energized directly from trolley. It is insulated for the alternating current line voltage and is protected by a copper ribbon fuse with magnetic blow-out. Fig. 404.

A single fuse of the magnetic blow-out copper ribbon type is used for protecting the motor circuit when operating either A. C. or D. C.

Both the alternating and direct current circuits are protected by suitable lightning arresters.

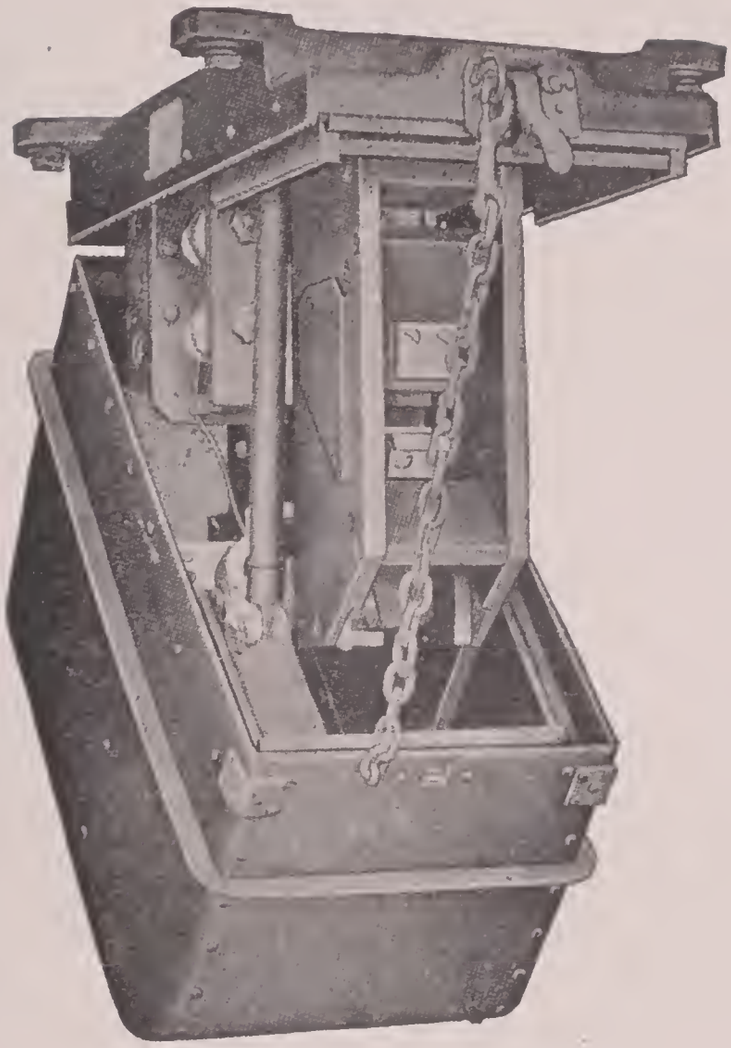


Fig. 403. Direct Current Switch.

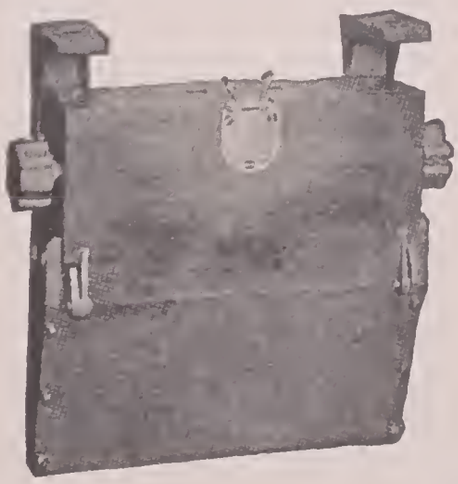


Fig. 404. Fuse Box for D. C. Circuits.

Cut-Out Switches.

A cut-out switch is used in connection with each pair of motors to disconnect a disabled motor when any car is operating individually as a single unit. As all the leads from each pair of motors run through their own cut-out switch, this is accomplished by simply turning the handle of the switch to the proper position.

Train Line.

The train line consists of a cable composed of ten conductors and runs through the entire train; the connections being made between the individual cars by means of suitable couplers. The master controller is connected to the train line at the connection boxes on each car, from which a multiple cable is run through the control cut-out switch to the operating coils of the contactors.

Auxiliary Circuits.

The circuits for the air compressor motor and those governing the lighting and heating of the car, are all protected by enclosed switches and fuses.

Air Compressor Motor.

The air compressor motor of the alternating-direct current compensated type; its exciting fields are connected in parallel for alternating current and in series for direct current operation. Fig. 392. The necessary

changes in connection are made through the medium of the commutating switch already described. The air pressure is regulated by a standard General Electric air compressor governor. Fig. 476.

Motor Connections.

The arrangement of the motor connections are dependent upon the service conditions required. The usual arrangement for both alternating and direct current operation is with all the motors on the car connected in series which permits of the use of fewer pieces of controlling apparatus and of less current carrying capacity than would be necessary if the motors were connected in parallel.

Method of Control.

During alternating current operation the car is controlled as follows:

On the first point of the master controller the motors are connected to a compensator tap giving approximately half voltage. After this point acceleration is obtained by cutting in more sections of the compensator winding, until on the last tap the motors are connected to the full working voltage tap. A small section of cast grid rheostat is cut into circuit during the instant of changing the motor connection from each compensator tap to the succeeding tap. This permits of an uninterrupted current supply to the motors without short-circuiting the various sections of the compensator winding. There are five steps on the master controller for alternating current operation, each constituting a running point, and seven

steps for direct current operation, the last step being the running one.

Changing from Alternating to Direct Current Operation.

The change from alternating to direct current operation is accomplished at a dead section in the trolley wire. At the instant the car enters this dead section whichever main switch is closed will open owing to the fact that the circuit energizing its retaining coil is broken. The car can run over this dead section at full speed and all that the motorman has to do to obtain the proper connections is to throw the commutating switch and close the main alternating or direct current switch, as the case may be.

LESSON 39.

Westinghouse Unit Switch System.

This system is operated by a small controller (Fig. 405) which has a center or off position and three positions on each side of the center for forward and reverse movements.

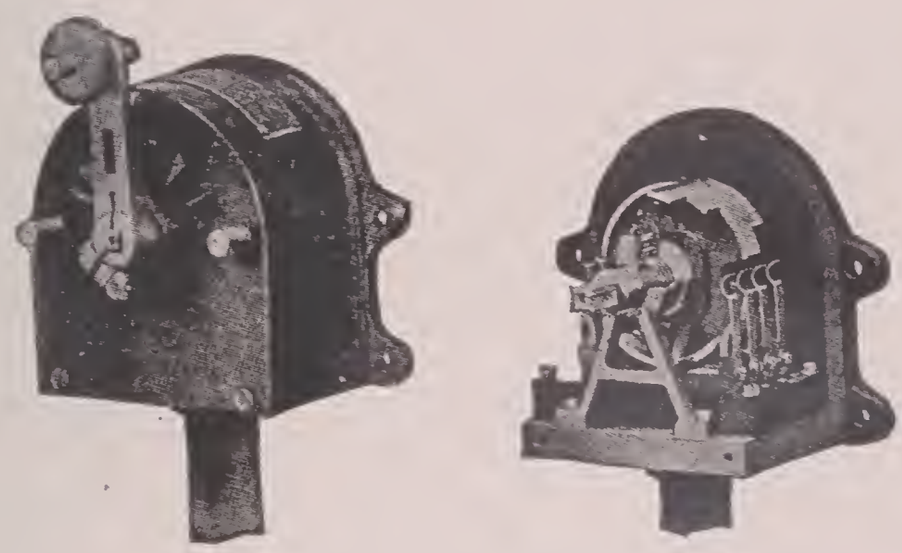


Fig. 405. Controller. Cover on and off.

The circuits which this controller opens and closes are supplied with current by a 14 volt storage battery, there being a duplicate set on each car.

The arrangement of motor circuits is done by a set of 13 switches or contactors which are opened and closed by small pneumatic cylinders drawing their supply through electro-magnetically operated valves, from a reservoir containing 70 lbs. pressure.

These electro-magnetic valves are operated by the circuits which are open and closed by the controller.

These 13 switches, with their air cylinders, magnetic valves and air reservoir, together with a blow out magnet to suppress arcing at switches, are all arranged into a

Switch Group.

This switch group is shown as it appears when bolted to the under frames of car in Fig. 406. With covers

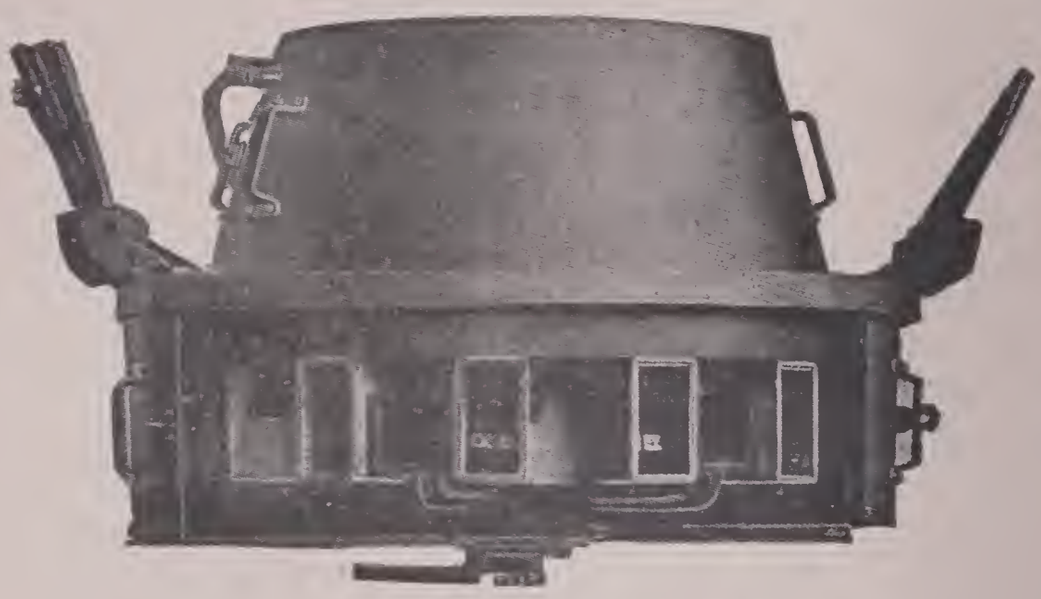


Fig. 406. Switch Group. Cover on.

removed it looks as in Fig. 407. The cast iron flange which is bolted to car frame shows plainly. Below are the magnetic valves, and at bottom are the arc chutes of the switches.

The sectional view in Fig. 408 shows the different parts of the switch group.

Air is supplied from the reservoir N by action of the electro-magnet L through a valve not shown by means

of a passage as on right side of figure (where the section comes between two cylinders) to the cylinder above the piston C.

The piston is forced down against the spring P, which will return piston to original position when air is exhausted.

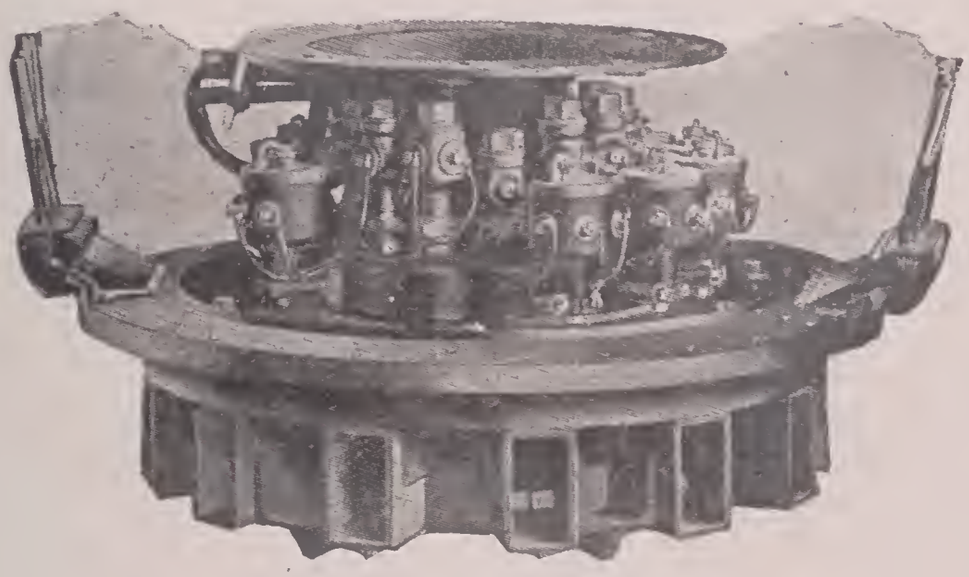


Fig. 407. Switch Group Opened.

This swings the outer end of arm E up against terminal H. The two studs M are the terminals of a motor circuit. They are insulated from the plate J which they are in. T also serves as the pole piece of the large magnet A which is the blow out for all switches.

The end of E has a rocker motion controlled by spring F, so that a rubbing contact is made with H. The extreme end of the contact piece D is a removable piece G.

The upper end of the piston rod engages some contacts at K. These interlocks control the passage of current to next valve magnet and thus produce an automatic acceleration.

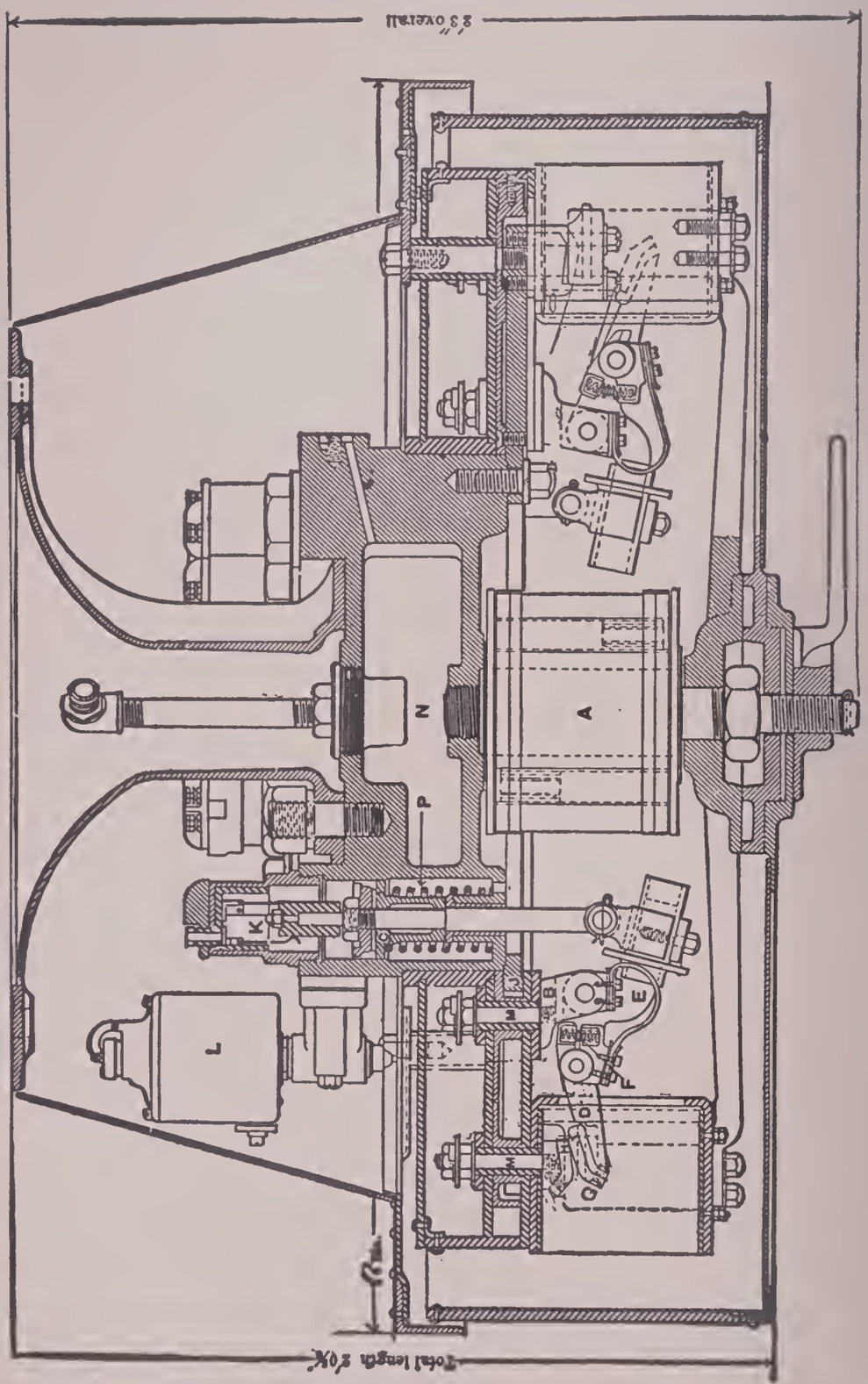


Fig. 408. Sectional View Switch Group.

Since the normal position of all switches is open, any failure of air supply will allow all switches to open and no harm will result.

Controller.

In the off position of the controller all unit switches are open and the reverser in position last used. The first position of controller throws the reverser (by operating its air valve) to forward or reverse position, according to whether handle is moved to right or left of center position. If reverser is already in correct position it simply stays there. In addition the motors are placed in series with all resistance in.

The second position puts the "lift up" and "retaining" wires in commission and by means of interlocks and the limit switch* (explained in Lesson 36) in four steps it cuts out resistance and places motors in full series.

The third position changes motors to parallel with resistance and then cuts out resistance until full parallel is reached.

Limit Switch.

This switch (Fig. 409) consists of a copper disk resting on two terminals which are in the pick up wire. The magnet which by means of an iron core raises the disk is in series with one of the motors. At any time the current input exceeds the proper amount the limit switch is operated and pick up wire opened, thus arresting further closing of unit switches. (See Lesson 36.)

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*This device is practically a *relay*, but is called a *limit switch* by Westinghouse Co. and a *current limit or throttle relay* by General Electric Co. In Lesson 36, it is simply called a *relay*.

Reverse Switch.

This switch (Fig. 410) with its magnetic valves and air cylinders arranges the motor field and armature cir-

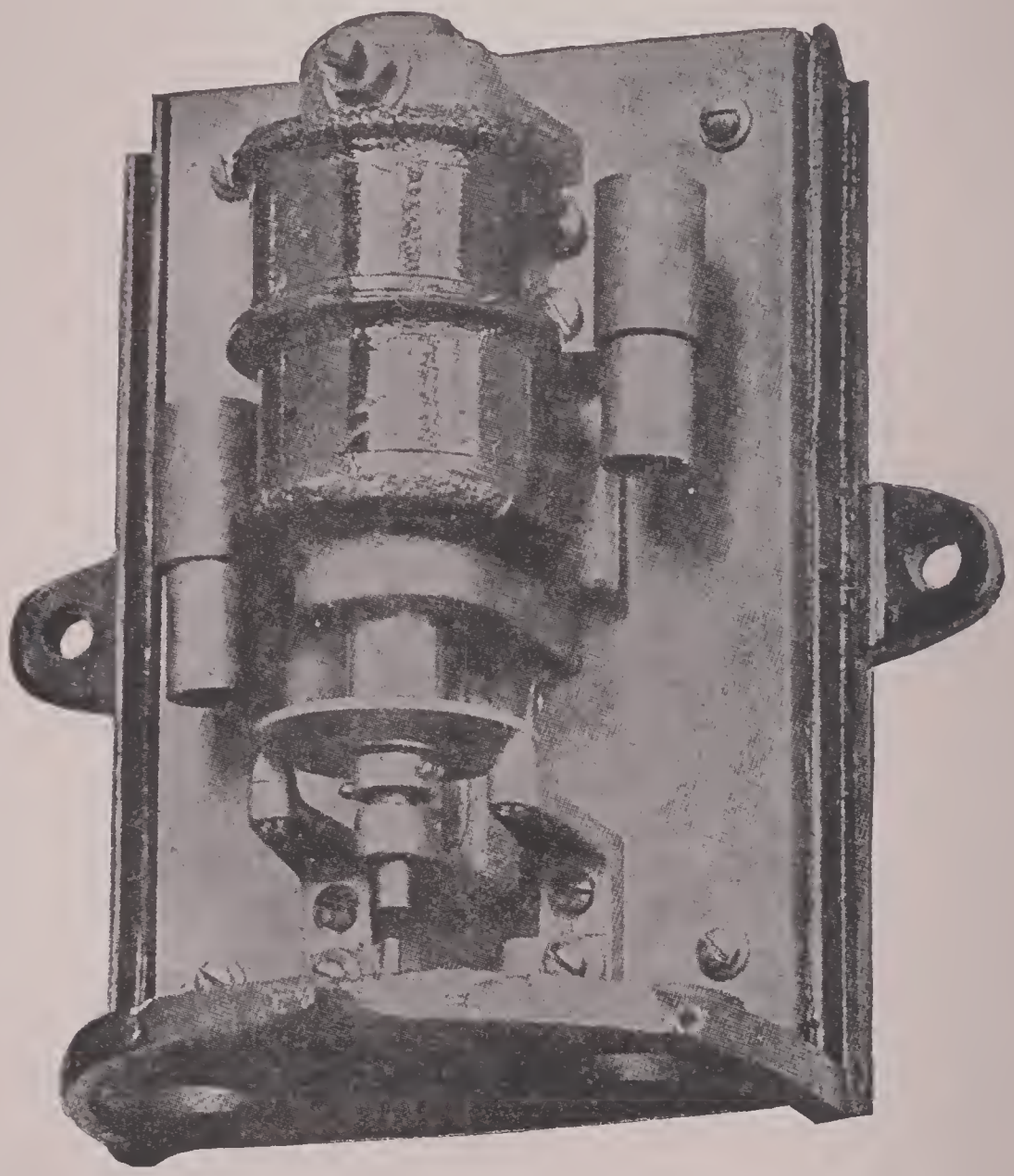


Fig. 409. Limit Switch.

cuits for forward or reverse running. It is provided with an interlock so that switch group is inoperative

unless the reverse switch is fully thrown, and making good contact, in the direction indicated by controller handle.

Storage Battery.

The current for magnet valves is furnished by two storage batteries of 7 cells each, with 40 ampere hours capacity. One battery is on operating circuits, while the other is being charged by the lighting circuit.

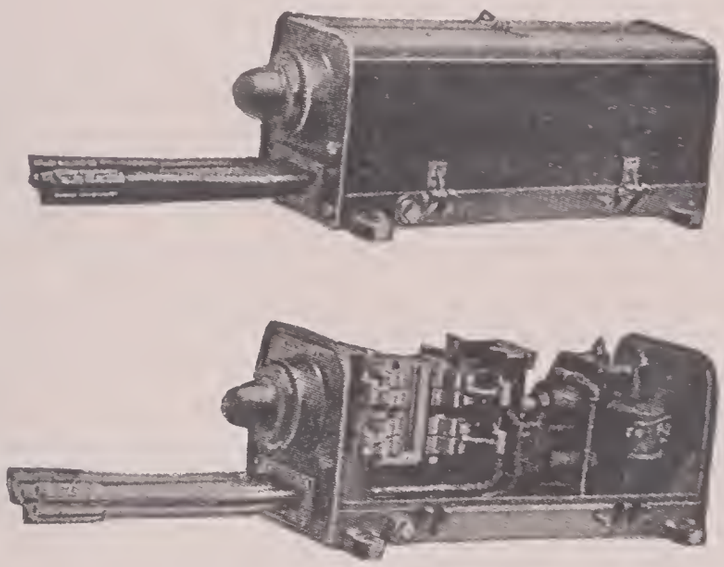


Fig. 410. Reverse Switch.

The positive side of the battery is connected to train cable through controller and the negative side to the valve magnets. In this way when a train cable circuit is completed at the controller current flows through valve magnet.

Circuit Breakers.

Each car has a circuit breaker which is reset after blowing by a magnet. All the breakers of a train can be reset at once by using the reset switch on the car the motorman is on. In a similar way in case of electrical troubles all the circuit breakers may be opened or tripped by a switch in motorman's compartment. Current may be cut off from any one car by opening line switch cut out without affecting operation of other cars.

Line Relay.

A device similar to limit switch, which is connected as a shunt across supply mains. It has a series resistance to protect it from the high voltage. Its copper disk is held against the terminals by the magnet against the tension of a spring. Should the voltage fail on trolley or third rail, this spring will open the circuit from the storage battery, the unit switches will open and no harm will result when voltage is suddenly re-established.

Operation of System.

Fig. 411 gives a wiring diagram of the unit switch control, the operation of which will be better understood after a study of Fig. 412.*

*In studying this and other diagrams, if a few pieces of paper be cut of such a size as to just cover the numbers of the switches or contactors, and as the text says the switches close, cover the numbers, the circuits formed will be closely indicated.

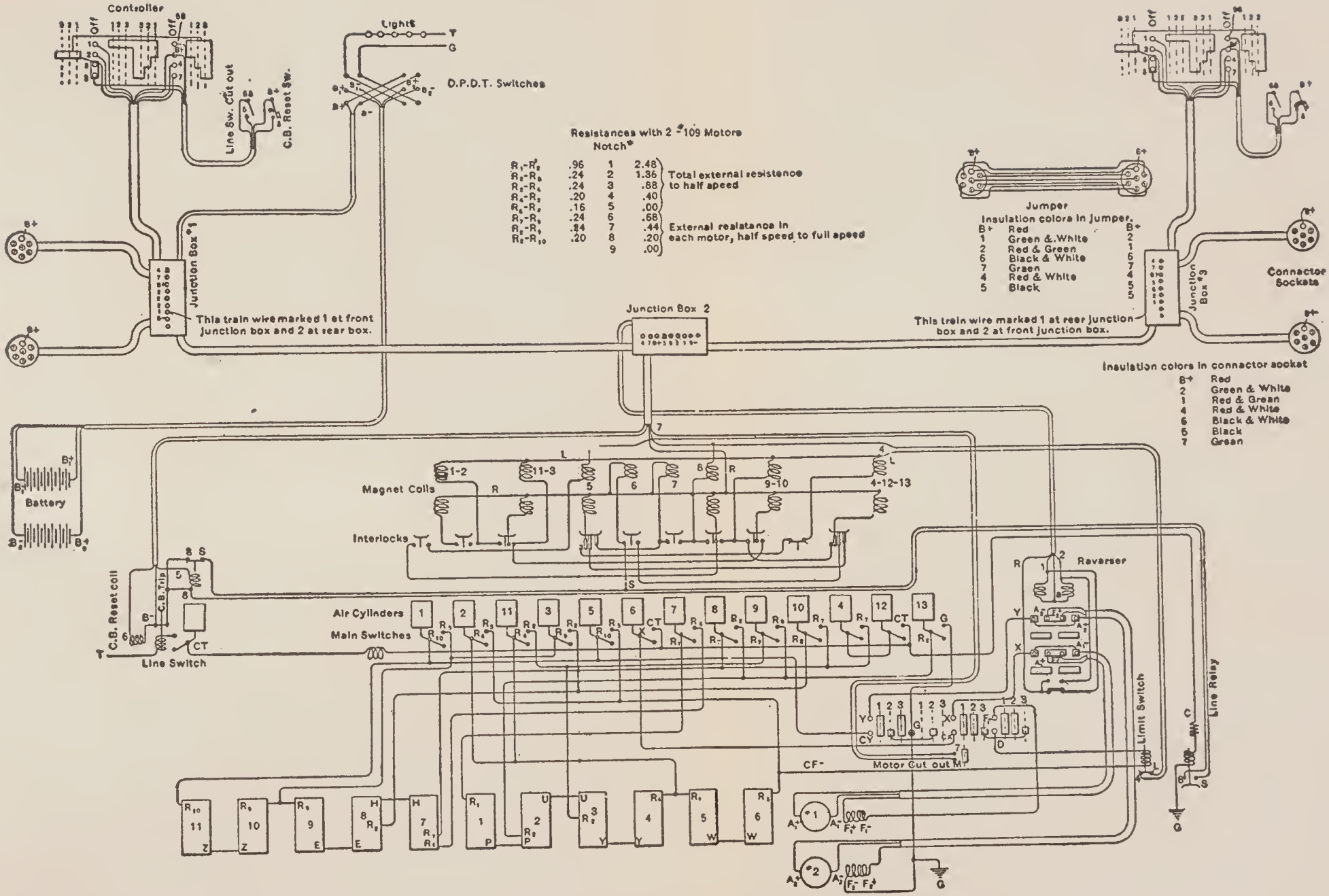
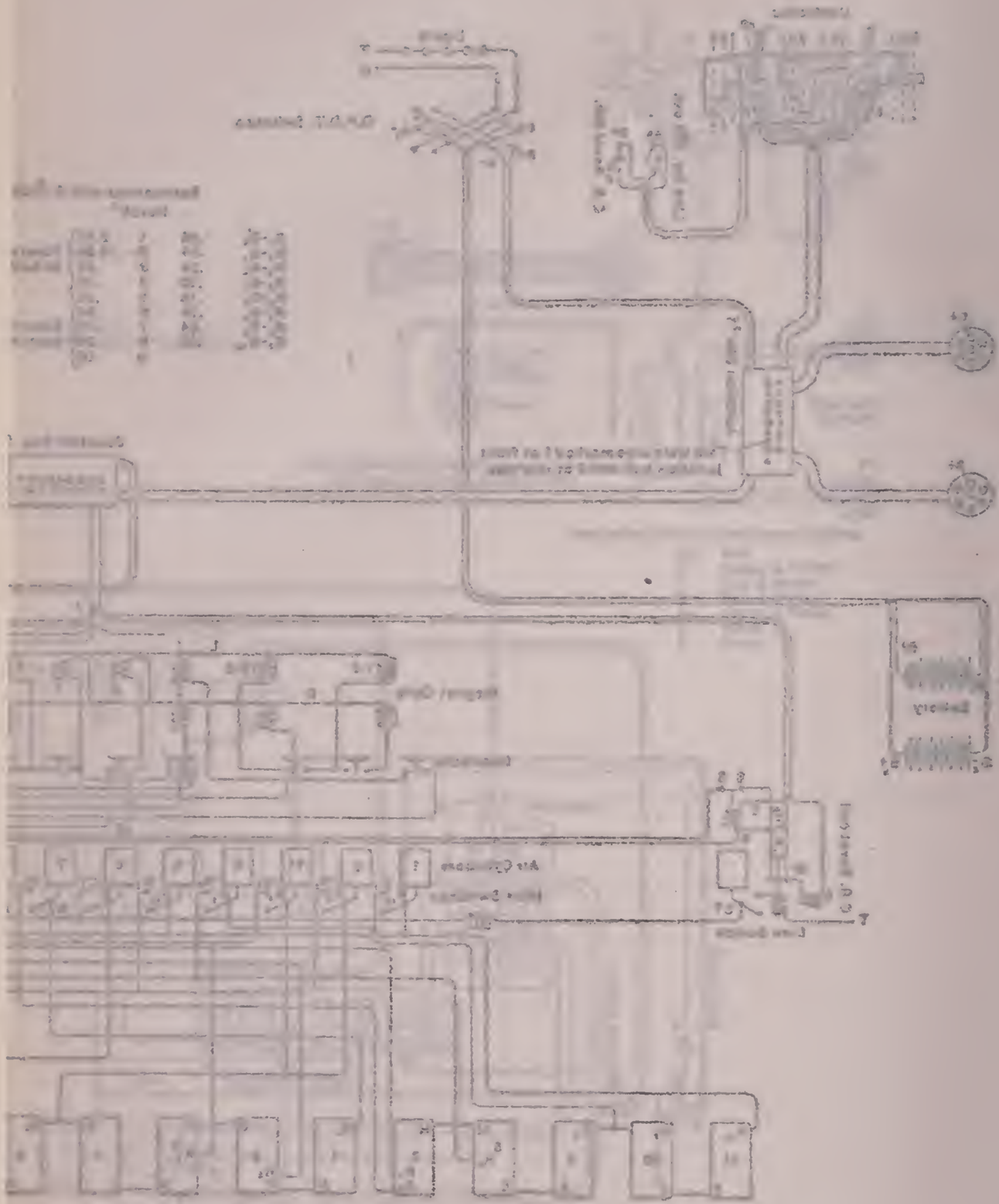


Fig. 411. Wiring Diagram of Unit Switch Control.



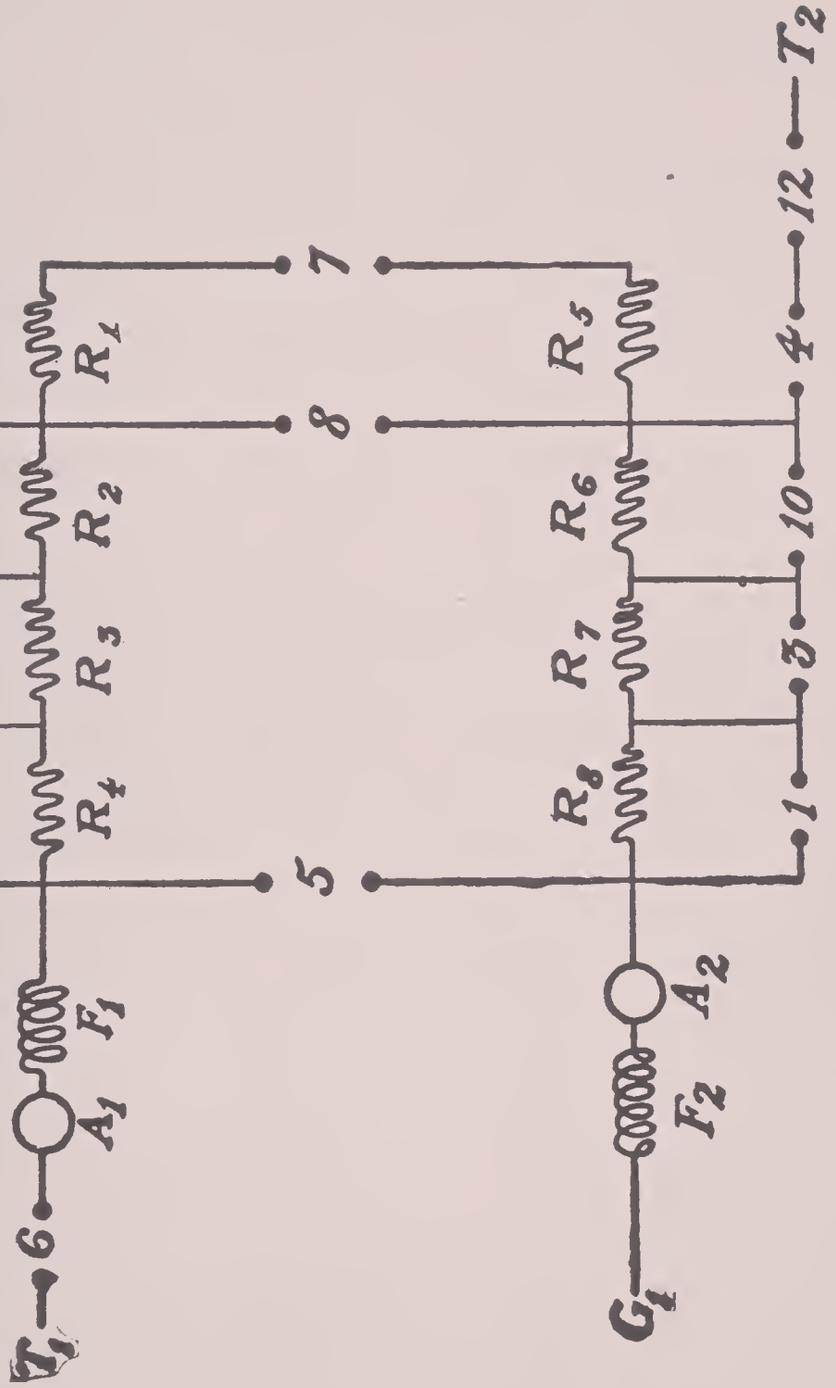


Fig. 412. Diagram of Motor Control. Unit Switch System.

With controller on second point the following things happen: Switch 8 is closed, cutting out resistances R1 and R5;* the interlock† on 8 closes switches 9 and 10. Looking at Fig. 411, where the interlocks are shown directly above the air cylinders of the switches, you will see that when 9 closes its interlock closes and when 10 closes its interlock opens.

It is the closing of interlock on 9 which closes switches 11 and 3, cutting out more resistance. Switch 3 has no interlock, but the interlock on switch 11 closes switches 1 and 2, thus placing motors in full series.

With controller on third point all these switches remain closed and 5 also closes. This does not produce any electrical change, but through its four contact interlock it opens switches 7, 8, 9-10,‡ 11-3, 1-2. It does this to prepare circuits for next change, and it keeps the motors in series itself by cutting out all resistance.

Now that switch 10 is open its interlock is closed again (Fig. 411) and current flows from the low contact on interlock 5 to the magnet coil 4-1, which closes switches 4-12-13.§

The state of affairs is now such that if switch 5 were

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*Because current will flow around the low resistance shunt instead of through resistance grid.

†Interlocks move down when switches close.

‡These switches are mentioned together in this way, because they always open or close together, being controlled by the same magnet valve. See Fig. 411.

§Because when switch 4 closes its interlock energizes lower coil which is marked 4-12-13. This coil closes switches 12 and 13, and keeps switch 4 closed, even though later switch 10 will close and open its interlock.

to open, the motors would be in parallel with all resistance in.

When controller is on first point switch 6 is closed, its interlock closes switch 7. The motors are then in series with resistance.

The interlock on 4 has right hand finger short enough so that when switch is closed coil 5 is cut off of circuit and switch 5 opens thus, placing motors in parallel with resistance. Although 12-13 close a fraction of a second before 5 opens no harm could result, for the state of affairs is as follows:

There is a circuit from T_1 to G_1 containing two motors in series; perfectly safe. A circuit from T_2 to G_2 containing resistance R_2, R_3, R_4, R_6, R_7 and R_8 amounting to 1.36 ohms; sufficient to prevent a short circuit. A circuit between T_1 and T_2 containing a motor and the resistance R_8, R_7 and R_6 also perfectly safe.

The interlock on 4 when closed energizes the short left hand contact which closes switches 9-10. Then in succession as described before switches 3-11 and 1-2 close, thus placing motors in full parallel.

Automatic Acceleration.

In the system of automatic acceleration described in Lesson 36 the contactor coil was shifted from pick up to hold up circuit.

In the unit switch system most of the valve magnets of the air cylinders have two operating coils called the pick up and retaining coils. The pick up coils are in circuits affected by the action of limit switch and the retaining coils are in other circuits.

Thus the controller and interlocks may arrange circuits so that a certain switch would close were it not that the circuit is open at the limit switch. As soon as that switch closes the valve magnet operates and switch closes.

If a certain switch is being held by the retaining coil the action of limit switch has no effect on it.

In Fig. 411 the wire L or lifting circuit comes from the limit switch, while wire R or retaining circuit comes directly from battery.

LESSON 40.

Locomotive for the New York, New Haven and Hartford Railroad Using Either Alternating or Direct Current.*

General System—The New York, New Haven & Hartford Railroad Company has started the electrical operation of their main line between New York City and Stamford, Conn., a distance of over 33 miles. That portion of the road which lies between the Grand Central Depot and Woodlawn, New York, utilizes the tracks of the New York Central Railroad and constitutes a portion of the electrical zone of that company within which the direct-current third-rail system is installed. Between Woodlawn and Stamford the road is equipped with the Westinghouse single-phase alternating-current system and the trains will be operated by electric locomotives which take alternating current from the overhead trolley line. The power station of the New Haven Company is located at Riverside, Conn., three miles from Stamford. The power equipment includes three Westinghouse-Parsons horizontal steam turbines driving 25 cycle, alternating-current generators of the revolving field type, which have a rated continuous capacity of 3,750 kw. each when running single-phase and of 5,500 kw. when supplying a three-phase service. The generator armatures are designed for

*To Railroad Men (a monthly magazine) we are indebted for cuts.

both single-phase and three-phase connection. They are wound for 11,000 volts and are connected direct to the trolley system. Absolutely no transforming stations or reducing transformers along the line will be required, but the entire system will be operated direct from a single central station without the interposition of substations or auxiliary apparatus of any kind between the switchboard and the cars. This desirable simplicity is made possible by the alternating-current system and the high trolley e.m.f. which will be employed. It is probable that, with a service equivalent to that now given by steam locomotives, electrical operation can be extended a distance of 20 miles beyond Stamford without the use of a higher transmission potential or the introduction of transforming stations.

High Potential Trolley Line—The overhead construction is supported from steel bridges which will be located every 300 feet and which will normally span from four to six tracks, though on certain portions of the road longer bridges will be employed. Every two miles the bridge is made of a specially heavy construction—forming an anchor-bridge to make the overhead structure even more secure. The trolley wires are hung from steel messenger cables which, in turn, are supported by heavy insulators mounted upon the steel bridges. Each trolley wire is suspended from a pair of steel messenger cables by triangular supports, forming a double catenary suspension of great strength and stiffness. The triangular supports are placed about ten feet apart. The messenger cables will have a total sag of about six feet, while the trolley wire itself will be held in a practically horizontal position.

The trolley system is divided into sections approximately two miles in length, each section being separated from its neighbors by heavy line insulators. Adjoining sections will be connected through automatic oil-type circuit breakers. If a short circuit or other trouble occurs in any section, therefore, it can be cut out without disturbing the operation of other portions of the line. Two feeder wires will be carried the whole length of the alternating-current line and will be so connected to the various sections of the trolley system by automatic switches that any section of four or more trolleys can be cut out of service and those beyond kept in operation.

The trolley wires will be held normally at a height of 22 feet above the track. The overhead system is designed with a safe margin to meet the stresses imposed by the most severe conditions—such as high winds or heavy coatings of ice.

Locomotives—Thirty-five locomotives are to be furnished by the Westinghouse Company, suitable for operation on the direct-current division between the Grand Central Depot and Woodlawn, and on the alternating-current portion of the line between Woodlawn and Stamford. Ten locomotives have already been constructed.

The frame, trucks and cab of the locomotive were built by the Baldwin Locomotive Company, according to designs developed with the co-operation of the New Haven Railroad and the Westinghouse Electric and Manufacturing Companies.

The Frame—As the entire space between the wheels is occupied by the motors, it was impossible to transmit the draw-bar pull through the center line of the locomotive; so the entire strain is carried by the strong plate girders

which make up the locomotive frame. A Westinghouse friction draft gear is mounted directly underneath the box girder at each end and is applied to two steel bumpers laid horizontally between vertical gusset plates on the ends of the side channels.

The Trucks—The running gear consists of two trucks, each mounted on four 62-inch driving wheels. The trucks have side frames of forged steel to which are bolted and riveted pressed steel bolsters which carry the center plates. The weight on the journal boxes is carried by small semi-elliptic springs with auxiliary coiled springs under the ends of the equalizer bars, to assist in restoring equilibrium. A very strong construction is secured without excessive weight by the use of bolsters 30 inches wide at the center plate and extended to nearly double that width at the ends which are bolted to the side frames. Center pins 18 inches in diameter transmit the tractive effort to the frame. They are well lubricated to permit free motion on curves. The truck pedestals are provided with wedge and gib adjustments to take up wear, and the bearing brasses are easily removable by hand. The distance between truck centers is 14 feet, 6 inches.

Cab—The cab is formed of sheet steel mounted on a framework of Z bars which supports the walls and roof. Windows are provided at each end, giving an outlook on both sides and in front of the locomotive; and the driver is so close to the front that he can see the track a very few feet ahead. This advantage is not possessed by any type of steam locomotive now in service. The master-controllers, auto-transformers, instruments, grid resistances, air operating valves, compressors and other auxiliary apparatus are mounted inside the cab upon an angle-iron

framework which is built into the cab and securely anchored to floor and roof. A clear passage-way is left through the center. Trap doors in the floor furnish easy access to the motors for inspection or repair.

Equipment—The equipment of the locomotive includes four gearless motors, controlling apparatus and auxiliaries.

Motors—The motors are of the gearless type, designed for operation on both single-phase alternating and direct current. They are wound for approximately 235 volts on alternating current and 275-300 volts when operated by direct current. They have normal rated outputs of 250 H. P. on the basis of ordinary railway practice, and a continuous capacity of 200 H. P. each. The locomotive therefore, has a continuous operating capacity of 800 H. P.

The motor frames are made of cast steel and are of a circular, skeleton form. They are divided horizontally into two parts in order to give access to the inside of the field or to the armature. A laminated core with slotted projecting poles is built up within this frame and wound with field coils of flat copper strap insulated between turns with asbestos and filled with an insulating compound which is heat-conducting and water-proof, so that a sealed coil is produced which can withstand moisture and internal heat. Copper bars are placed in slots in the pole faces and connected to form a continuous neutralizing winding which forms part of the circuit including the main field coils, the armature coils and the auxiliary winding, all in series. This auxiliary winding produces a magnetic field which opposes and neutralizes the reaction of the armature. It is so formed that it need not be disturbed in order to remove the main field coils.

The armature core is built up of soft steel punchings which are assembled on a cast iron spider and held in place and keyed to prevent their turning. The surface is slotted and the armature winding is arranged in three layers. The two upper layers are composed of copper strap connected to form the usual direct-current type of winding. The third layer constitutes the preventive winding. It is connected between the commutator and the main winding. This preventive winding is so proportioned as to prevent sparking, due to the normal working current and that which is produced in the coil under commutation, when short-circuited by the brush in an alternating field. The individual coils are insulated along their entire length by overlapping layers of mica tape, and each group is further insulated from the core by a molded mica cell. The completed winding is held firmly in position by insulating wedges. The ends are banded down against the coil supports.

Suspension—The weight of each motor is carried on a frame which passes over the wheels and side frames and rests on the journal boxes. Each frame carries four bolts which receive the weight of the motor and each bolt is fitted with a heavy coil spring at its lower end through which all weight is transmitted to it, so that the motor is carried on very flexible springs and is independent of the truck frame. The torque of the motor and the jar caused by sudden starts and stops are transmitted from the motor to the truck through heavy tie-rods which affect the motion of the motor only lengthwise of the locomotive. The armature is not placed directly on a shaft but is built up on a quill through which the car axle passes with about five-eighths inch clearance all around. The

bearings which carry the field frame are mounted on this quill and from a flange at each end of the quill seven round pins project parallel to the shaft into corresponding pockets formed in the hub of the driving wheel. The torque of the motor is transmitted from these pins to the wheel through helical steel springs which are wound with their turns progressively eccentric, and which are contained between two steel bushings, the smaller of which slips over the pin and the larger fits in the pocket in the wheel. These springs are under compression both longitudinally and horizontally so that, at all times, they fill the pockets in the wheel but permit a vertical and a lateral motion. Their longitudinal compression between the quill and the segmental cover over the outer ends of the pockets in the wheel keeps the motor at all times midway between the hubs. The end play of the motor does not come directly on the wheels but is taken by strong coiled springs inside of the driving pins, which press against the covers in the outer ends of the spring pockets in the wheels. Though normally required to transmit only the torque of the motor and to keep the motor axis parallel to the axle, these springs are amply strong to carry the entire weight of the motor. They allow a total vertical movement of about ¾ inch. The torque of the motor is taken by heavy parallel rods which anchor the frame to the truck above and below the axle and permit vertical or side motion of the motor but prevent excessive bumping strains from coming on the driving springs. If these springs are compressed more than ¼ inch by the heavy centrifugal force exerted by the motor when rounding curves, the force is taken up by noses on the motor which fit into corresponding recesses in the cross ties between the side frames of the locomotive.

This suspension has the advantage of removing all dead weight from the axle, of driving through springs, and at the same time of having the motor thoroughly anchored to prevent undue strain on the driving spring. The only parts of the locomotive not spring supported are the driving wheels, axles and journal boxes.

Forced Ventilation—The motors are arranged for ventilation by a forced circulation of air which enters under pressure, is distributed throughout the motor and escapes through the perforated covers. In the floor of the cab there is a natural conduit formed by the side channels of the frame, the floor and side walls of the cab, and a lower plate, through which air is carried to the motors, transformers and resistances. This method of cooling improves the continuous capacity of the apparatus and is, in a large measure, accountable for the high continuous rating of the motors which almost equals that on the one-hour railway basis. The air furnished to the motor may be taken from the inside of the cab and can therefore be kept relatively clean and dry.

Current Collection—On the direct-current part of the line current is taken from the third-rail system by eight collecting shoes, four on each side of the locomotive, arranged in pairs of two each. There are two pairs on each side, one at each end, for the purpose of bridging such gaps as may occur in the third-rail system. The direct-current contact shoes are designed to work on two forms of third rail—one in which the shoe runs under the rail, and the other on top of the rail. To collect alternating current from the high-potential overhead trolley line, the locomotive is equipped with two pantagraph type, bow trolleys, each of which has a capacity sufficient to

carry the total current required by the locomotive under average conditions—two being provided to insure reserve capacity.

The Control System—On direct current the motors are controlled in series parallel as in ordinary railway practice. In alternating current operation no resistance is used in the regular run, but a small resistance, which constitutes a preventive device to diminish the short-circuiting effect when changing from one transformer tap to another, is employed in passing from one working step to the next. There are six alternating-current voltages or running points, corresponding to six taps from the auto-transformers, and there are a small number of midway steps which are used only in passing between working notches. Experience has shown that the number of steps required in alternating-current operation to give a smooth acceleration is considerably lower than in direct-current practice. In consequence, the controller is so arranged that on alternating current about half as many steps are used as on direct current. Tests so far conducted show that the acceleration on both alternating and direct current is very smooth.

There is one feature of the direct-current control which is not generally found at the present time in direct-current equipments, viz., the shunting of the field for higher speeds. In the series position in direct-current operation the motors have an efficient running point. It is usual railway practice to pass from the series to the multiple position without an efficient intermediate running speed. With the New Haven equipments, however, the type of motor used permits shunting of the field without impairment of commutation or operation and higher speeds are

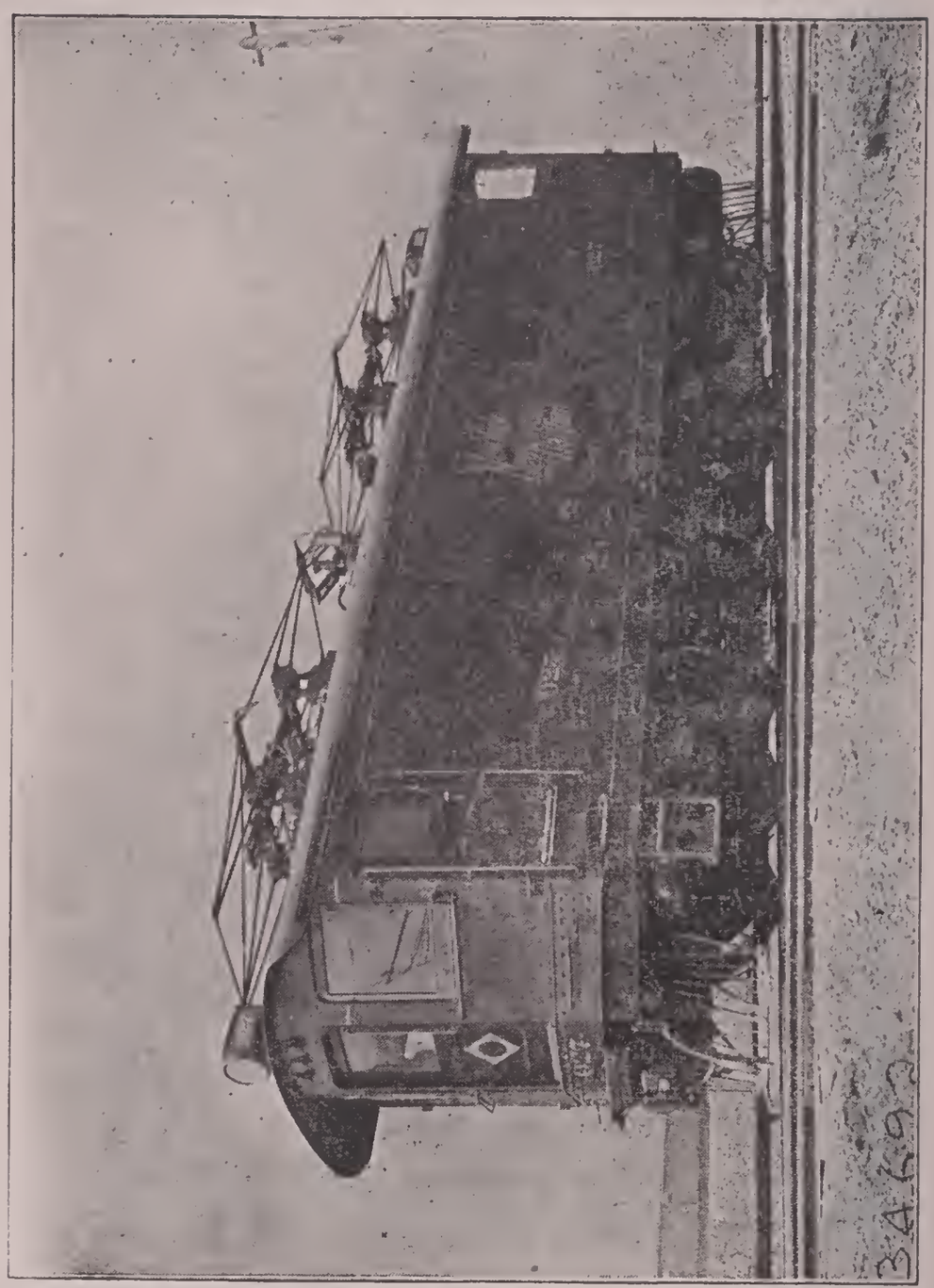

Fig. 413. New Haven Locomotive in D. C. Zone. A. C. Trolleys Down. Third Rail Shoes Down.

provided by shunting the fields before passing into multiple. In this way several efficient running points are obtained between the series and multiple positions; and tests have shown that these motors operate properly on direct current with their fields shunted down to half their normal strength. When operated on direct current, the current is fed directly to the motors. On alternating current, however, auto-transformers are required, as the alternating-current trolley voltage is 11,000. Two such transformers form part of each equipment—one mounted on each side of the cab floor to balance the weight. They are connected in parallel across the high voltage, but on the low-voltage side each transformer feeds one pair of motors through a separate control unit. This means that the control system when operated on alternating current, consists of two normally independent units.

The main controllers are the Westinghouse electro-pneumatic unit switch type. The design differs somewhat from that used in direct-current service, because of the fact that the switches, blow-outs, etc., must operate on both alternating and direct current, as many parts of the controller are common to both systems. The reversing switches are also parts of the unit switch groups. The main controllers are operated from master controllers at each end of the cab. The control system is arranged for multiple unit service, so that two or more locomotives can be coupled to the same train and handled by a single driver.

There are six switch groups, each containing unit switches. The two line switches are so connected in the switch groups that each carries the current supply to each pair of motors when they are operating in parallel com-

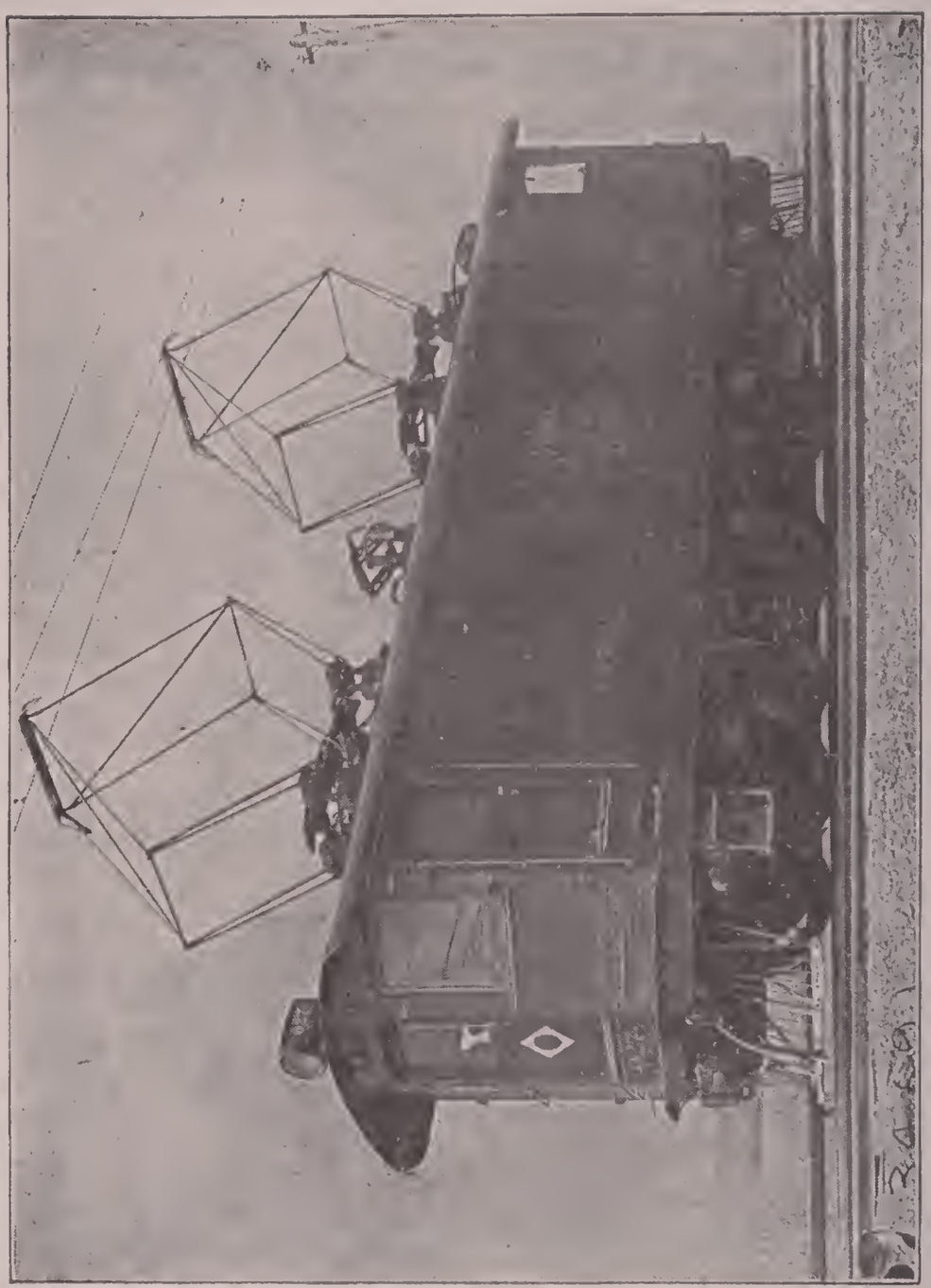

Fig. 414. New Haven Locomotive in A. C. Zone. A. C. Trolleys Up. Third Rail Shoes Up.

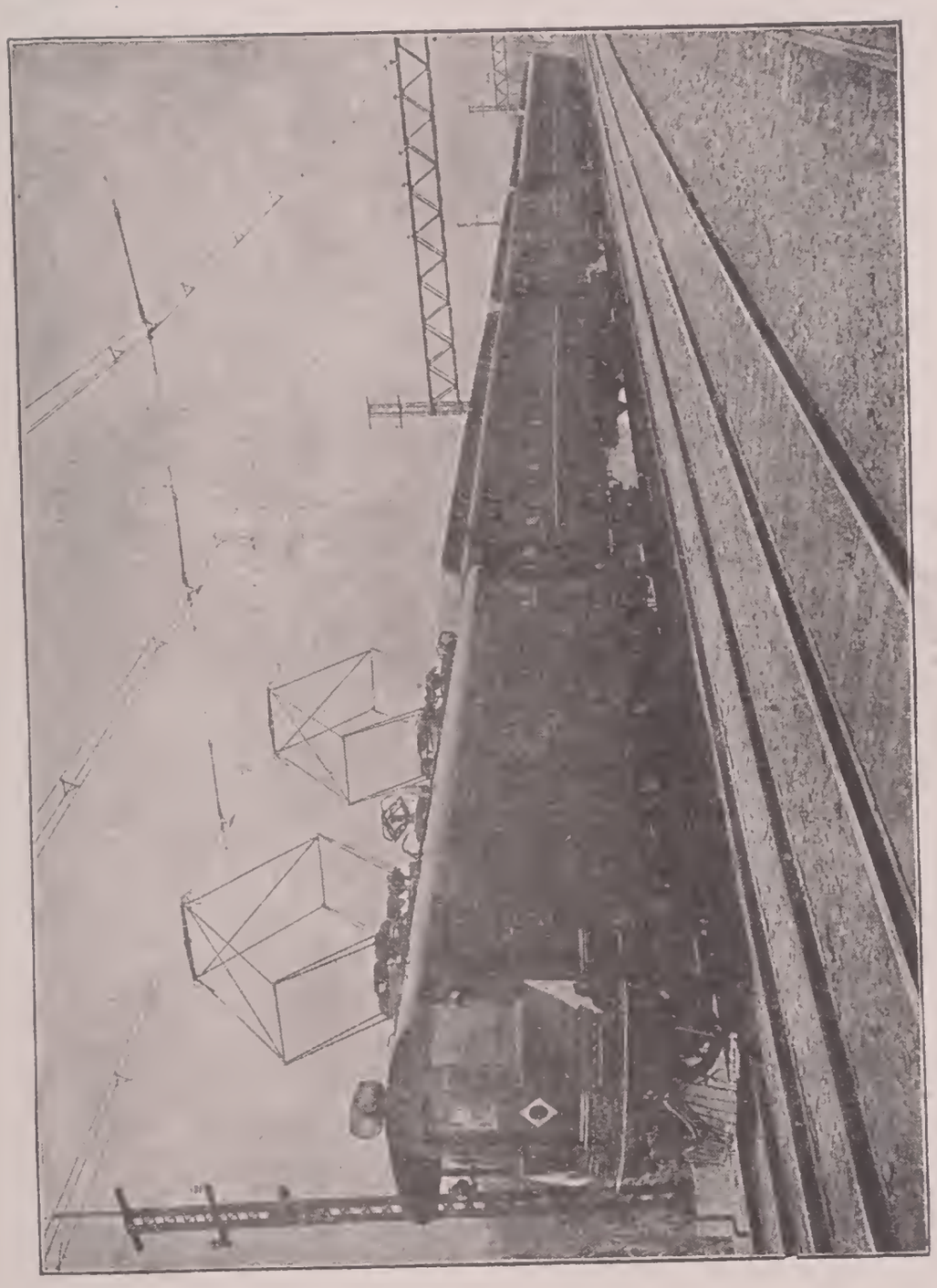

Fig. 415. New Haven Train.

bination. When the motors are in series, one of the line switches carries the current supply to all. Each line switch is provided with an overhead trip so connected that all of the switches of both switch groups as well as both the line switches open in case of an overload or short circuit on either pair of motors or in the circuit of either pair. The overload trip is automatically locked out when brought into action and cannot be reset until the master controller is returned to the off position.

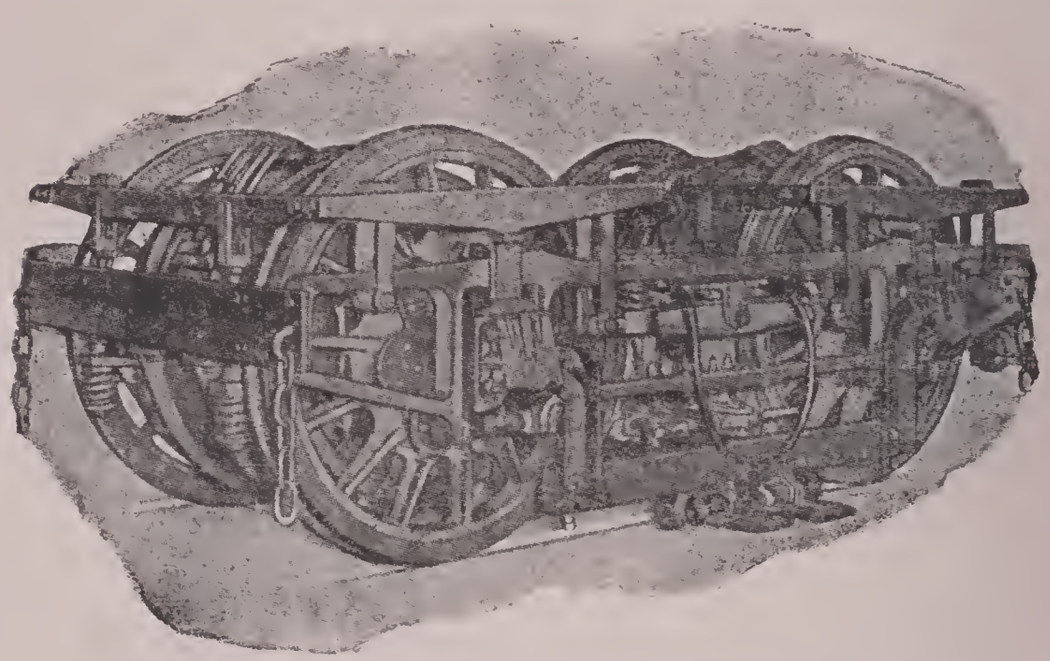

Fig. 416. One Truck of New Haven Locomotive.

The external resistances used in regulating the flow of current to the motors are arranged in two groups which are connected in series when the motors are in series, and in series with each motor when the motors are in parallel. The change over between the direct current third rail and the alternating current overhead system can be made easily and quickly even when the locomotive is running at full speed.

An ammeter is mounted in each end of the locomotive in plain view of the operator when at the master controller.

The master controller is of the drum type and is operated by a lever which moves through an arc of about 60 degrees, with notches and latch wheel to define the dif-

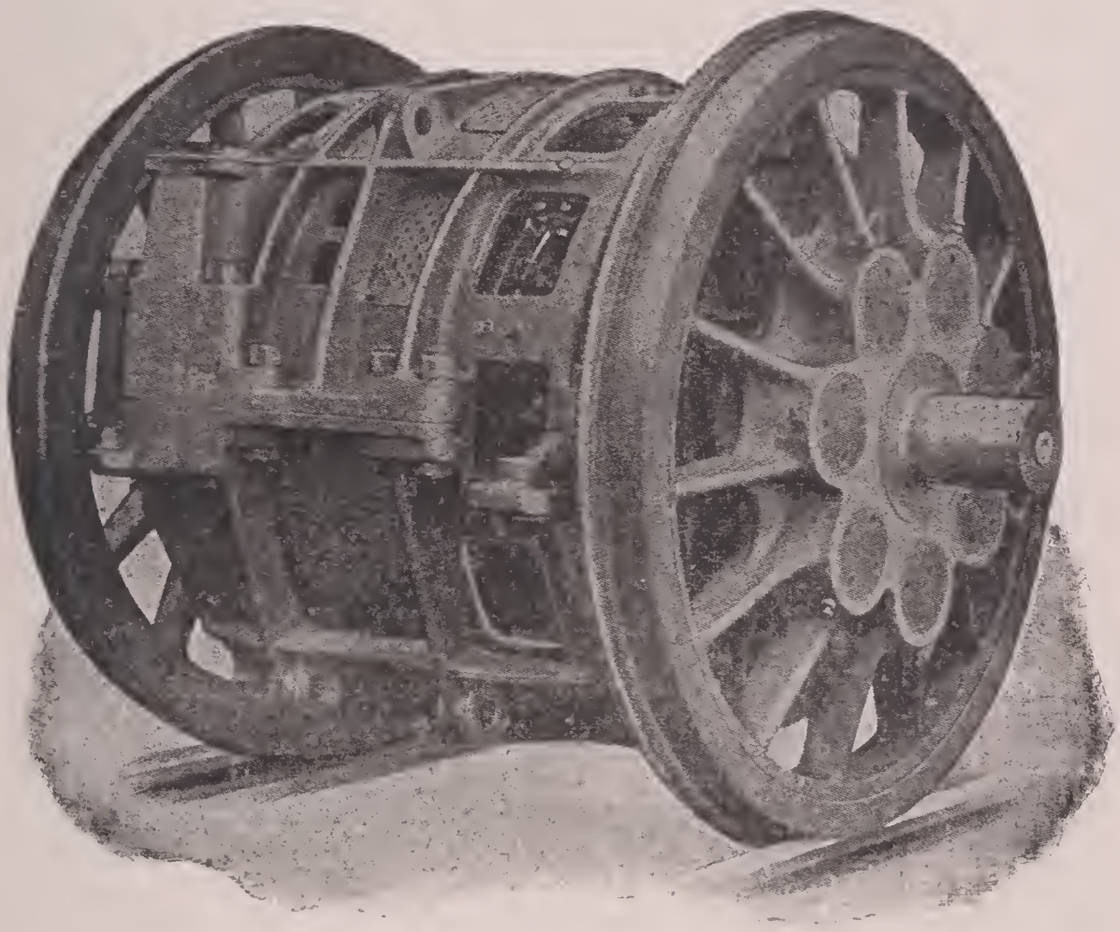

Fig. 417. One Complete Motor for New Haven Locomotive.

ferent positions. Reversing is accomplished by a separate handle which interlocks with the main lever. When the master controller is in the off position, connections are so established that all circuit breaker trips which may be open are closed by the simple closing of a small switch

conveniently located in the locomotive cab. Current is supplied to the control circuits by two sets of 7-cell storage batteries, each of which has a capacity of 40 ampere-hours and weighs 150 pounds.

In connection with the switch groups, cut-out switches are provided so that either pair of motors may be cut out by simply rendering certain switches inoperative. It is thus possible to cut out the motors without manipulating the main circuit.

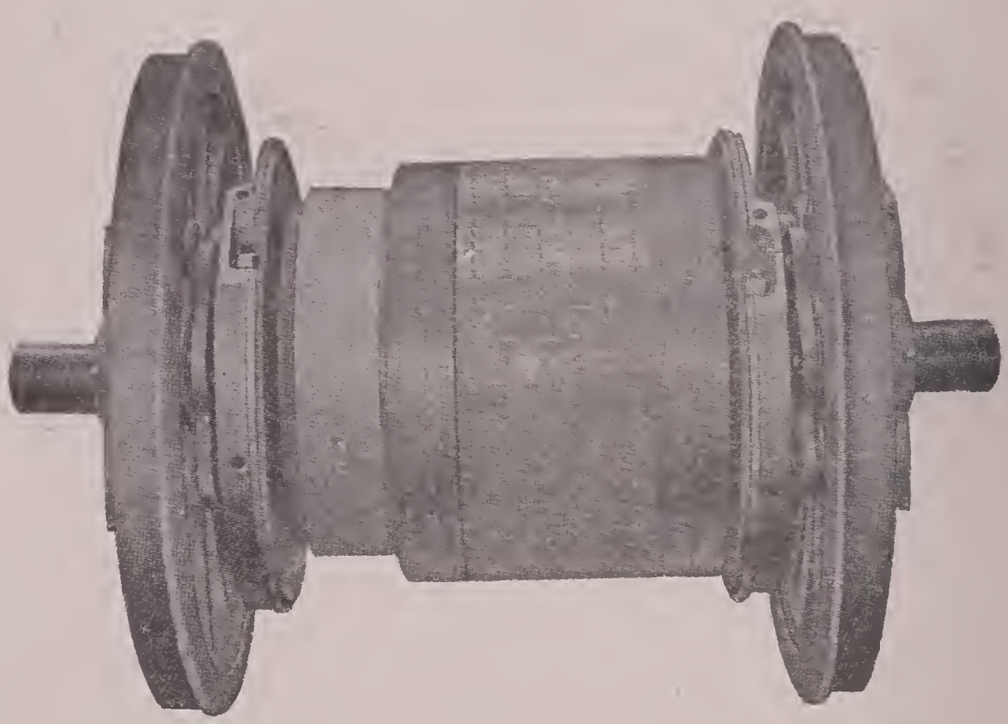

Fig. 418. Complete Armature Mounted on Locomotive Axle.

Auxiliaries—The auxiliary equipment includes two air compressors driven by motors which can be operated on either alternating or direct current; two blowers driven by similar motors and which furnish air to the transformers, motors and direct-current rheostats; oil circuit-breakers for the high-tension circuits; switches to change the equipment from alternating to direct current; a steam

generator to supply heat to the railway coaches in cold weather; a complete Westinghouse air brake equipment, signal apparatus, automatic bell ringers, whistles, sanding apparatus, etc.

Dimensions and Performance—The New Haven locomotive measures 36 feet, 4 inches over the bumpers and weighs approximately 85 tons. It is capable of handling a 200-ton train in local service on a schedule speed of 26

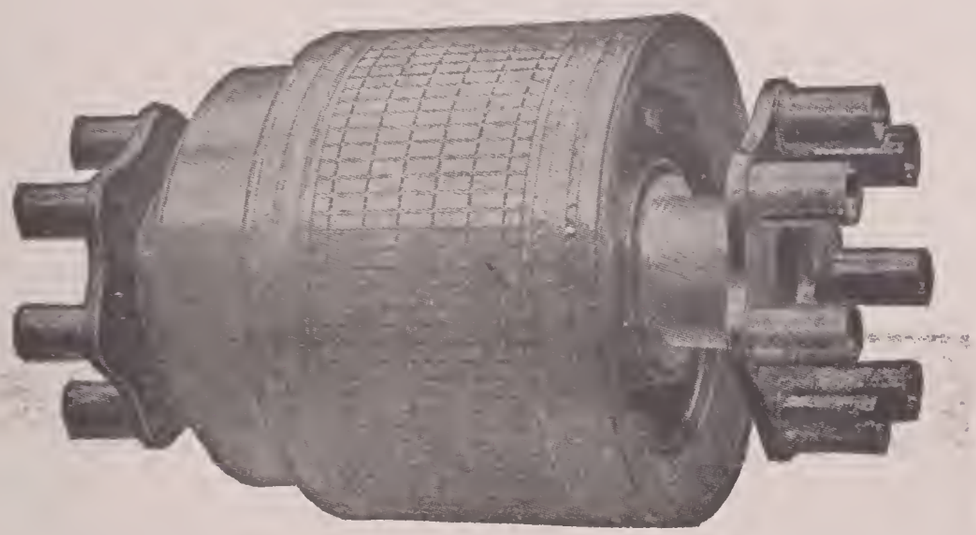

Fig. 419. Armature Mounted on Quills.

miles an hour, with stops averaging about two miles apart —making in such service, a maximum speed of about 45 miles per hour. It can also handle a 250-ton train on through service with a maximum speed of about 60 miles an hour. With heavier trains it is planned to couple two or more locomotives together and operate them in multiple.

Tests—The tests which have been made on the first locomotive equipped show that it will, without difficulty, meet all the requirements for which it has been designed.

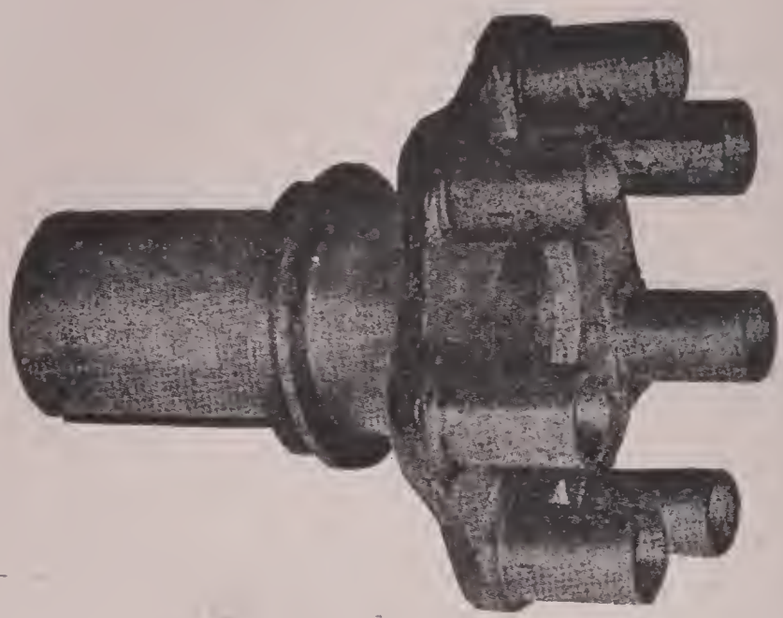

Fig. 420. Driving Quill.

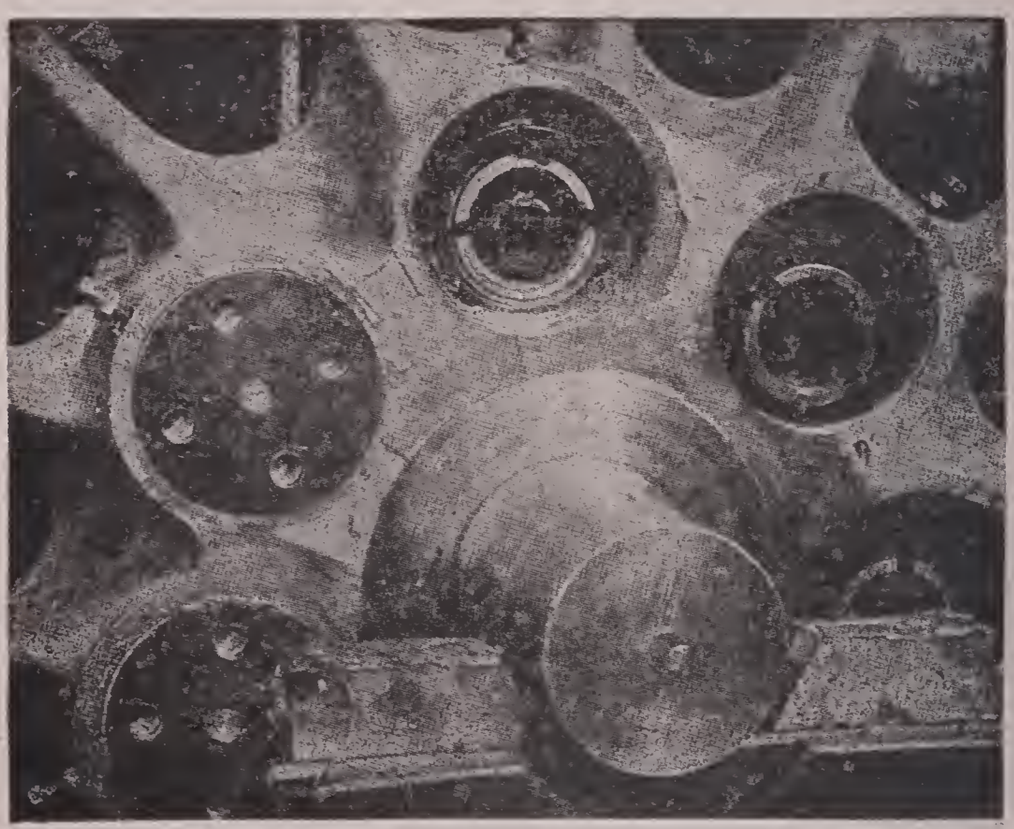

Fig. 421. Pockets in Driver for Fingers of the Quill.

This locomotive has, on actual test, repeatedly accelerated a 200-ton train at a rate of .5 of a mile per hour per second, which is in excess of the rate required by the service conditions of the New Haven road. The locomotive has been operated at speeds above 60 miles per hour without difficulty.

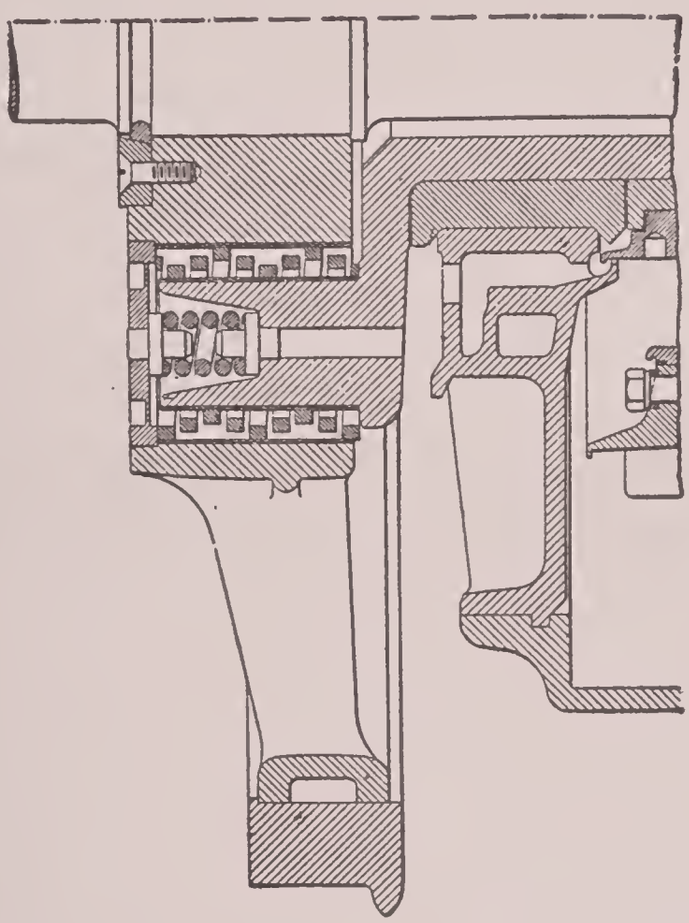

Fig. 422. Method of Placing Springs Between Quill Fingers and Driving Pockets.

In Fig. 413 is shown a locomotive standing in D. C. zone with both trolleys and shoes down; when standing in A. C. zone, as in Fig. 414, both trolleys and shoes are up. In Fig. 415 is shown a regular New Haven train.

One of the two trucks under the locomotive is shown in Fig. 416. One complete motor mounted on its pair of drivers is shown in Fig. 417. The eyes for the tie rods, three on each side show plainly. On a level with axle are two lugs on each side, through which the four suspension bolts pass.

Fig. 423. Master Controller.

The complete armature with the end plates which support field, are shown in Fig. 418, mounted on the axle. Fig. 419 shows armature with its driving quills. Fig. 420

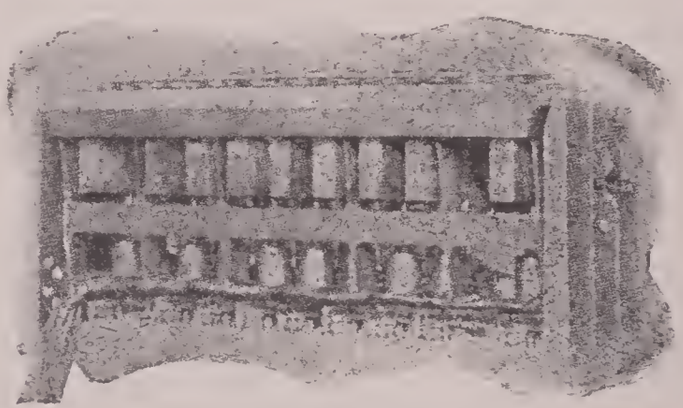

Fig. 424. Unit Switch Group.

shows one driving quill in greater detail. Note the central hole through which locomotive axle passes. The key way to connect armature spider to quill is shown. The

driving pegs of quill are hollow to contain the end thrust springs.

Fig. 421 shows the outside of driver with the driving pegs in the pockets of driver. Two of these pockets have the cover plates in position. Fig. 422 gives the details of the springs.

Fig. 425. Speed Recorder.

Fig. 423 shows the master controller, and Fig. 424 a group of unit switches.

Each locomotive has a speed indicator whose mechanism is shown in Fig. 425. It being a magneto frictionally driven from a locomotive driver.

LESSON 41.

New York Central Motor Cars.

The one hundred and twenty-five steel motor cars of the New York Central are of pressed steel even to doors and window casings and ornamental mouldings. They are 60 feet in length over all with a wheel base of 45 feet.

They are designed to pass around a curve of 135 feet radius.

The light weight of motor cars and trailers is 102,600 and 78,600 lbs. respectively, giving weight per passenger of 1,603 and 1,228 lbs. respectively. The weight of the usual 60 foot wood coach is 61,800 lbs., or 965 lbs. per passenger. In spite of this extra weight the total train of six cars is lighter than a steam train, the gain being due to absence of locomotive weight.

An electric fan is located in each end of car for cooling and ventilating.

The two 200 H. P. motors on the motor truck are controlled by the Sprague-General Electric Type M Control with automatic acceleration at rate of 1¼ miles per hour per second up to a maximum speed of 52 miles an hour.

The arrangement of motor control apparatus is shown in Fig. 426.

When controller is thrown to first notch forward wire number 4 (which will be referred to as W4) and wire number 2 (W2) are energized.

W4 goes through the reverser coils and through coils of contactors 11, 12, 1, 10 and thence to ground. This

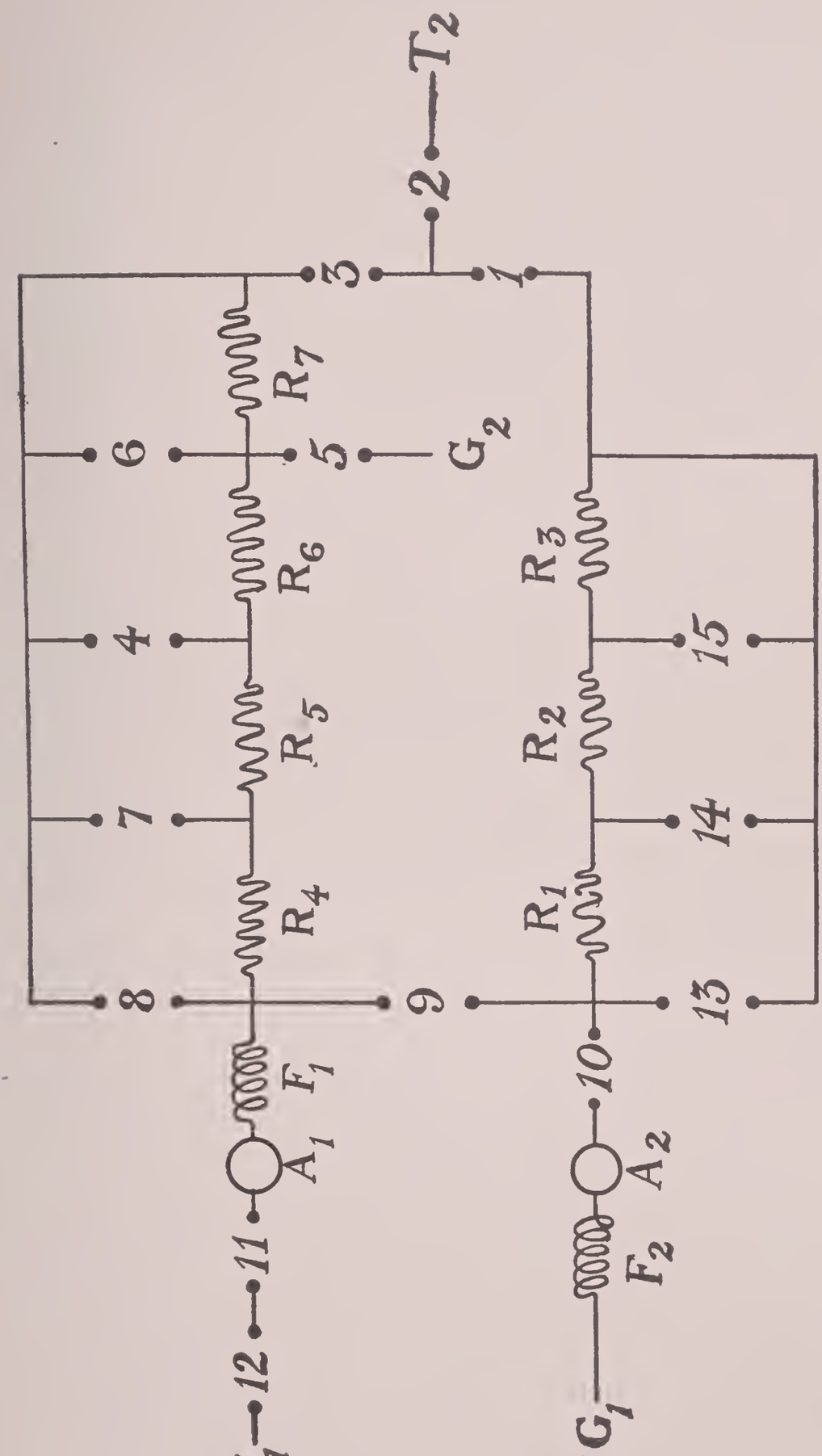

Fig. 426. Diagram of Motor Control, N. Y. C. & H. R. R. R. Motor Car.

swings the reverser into the forward position and closes the four series contactors 11, 12, 1 and 10.

W2 has its circuit closed at controller but completed through the interlock on contactor 12, so coil of contactor 3 is now energized; 3 closes and motors are in series with full resistance.

Turning controller to notch 2 places W1 in service. This is the pick-up wire. It goes to the throttle relay across its disk and up through a magnet which lifts the disk and then on through contactors 13, 6, 8. It does not close all these at once because as it is closing 13 it is also lifting the core of the throttle relay in order to break its own circuit. There is a slip joint between core of magnet and disk on throttle relay so that contactor 13 has time to close and throw its own coil (by means of interlock) over to W2, but contactor 6 does not have time to do this before throttle relay breaks circuit of W1.

The closing of contactor 13 cuts out R_1, R_2 and R_3 so that motors take more current.

It is this increased current passing through the series coil of the throttle relay that holds the disk up, continuing to keep pick-up wire (W1) open circuited until the current through motors dies down to its normal value.

Then throttle relay closes, W1 instantly picks up contactor 6, which itself gets on to W2 before the throttle relay can open W1. The rush of current holds relay up till the current falls again. Contactor 8 is then closed in same way and motors are in full series.

While this has been going on W2 has been trying to close contactors 4 and 7 but could not on account of interlocks until 13 and 6 were closed, then 4 and 7 close in succession and then 8 closes.

While moving from notch 2 to notch 3 the bridge contactor 9 is closed and 3 is opened. This makes no electrical changes, nor does the opening of 8, 7, 4, 6, 13.

When notch 3 is reached W3 is energized and contactors 2 and 5 close. This arrangement is safe because even in the lowest resistance circuit from T_2 to G_2 there is sufficient to prevent a short circuit. However, the closing of 2 and 5 by means of interlocks throws 9 open, placing the motors in parallel with resistance.

At notch 3 wire 1 is not connected, so motors stay in parallel with resistance till controller is moved to notch 4 which cuts in W1; thus starts the automatic closing of contactors. Due to the action of interlocks, when contactors 2 and 5 are closed the order of closing contactors by W1 is to close them by groups, each group awaiting the action of the throttle relay. 6-15-4 close, then 14-7, then 13-8, when the motors are in full parallel with no resistance.

Contactors 11-12-1-10 close when the reverser is thrown and are always closed unless controller is in off position.

The action of contactors for reverse motion is the same, except that W5 closes the contactors 11-12-1-10 and passing through other coil on reverser throws it into the position for backward motion of car.

On the reverse the full series position is as far as the acceleration will progress.

LESSON 42.

New York Central Locomotives.*

The locomotive, 35 of which are in use on the N. Y. C. & H. R. R. R., weighs about 100 tons and has 71 tons on its drivers. These are four in number, 44 inches in diameter. The driving wheel base is 13 feet.

A Pacific type steam locomotive has three driving axles, with 75 inch drivers, and the same 13 foot wheel base.

The electric and steam locomotives can take same curves, but the electric has the better grip on the rails due to the four driving axles and it has as much weight on drivers as steam locomotive has altogether.

At each end of the locomotive is a swiveling truck with one axle; these axles carry 36 inch wheels. From last driver axle to truck axle is 7 feet and from truck axle to end of locomotive is 5 feet more. This with the 13 foot driving wheel base gives a total length of 37 feet or 30 feet shorter than a steam locomotive.

Each driving axle is 8½ inches in diameter and has keyed to it a sleeve upon which is carried the armature core sleeve and the commutator hub, each separately keyed. The drivers are forced on the axles as usual, forming a rigid and solid unit.

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*To Mr. J. C. Irwin and Mr. S. A. Bickford, both of New York Central, are due thanks for completeness of following information.

Fig. 427 shows one of these units standing inside its field coils with one driver removed to afford a better view.

The top bar is not a mechanical part of the frame, but is one of the two pieces of soft steel, running the length of the motors to improve the conductivity of the magnetic circuit.

Since the commutator ends of the motors are the lighter, these bars lie on that side of the frame, preserving a mechanical balance.

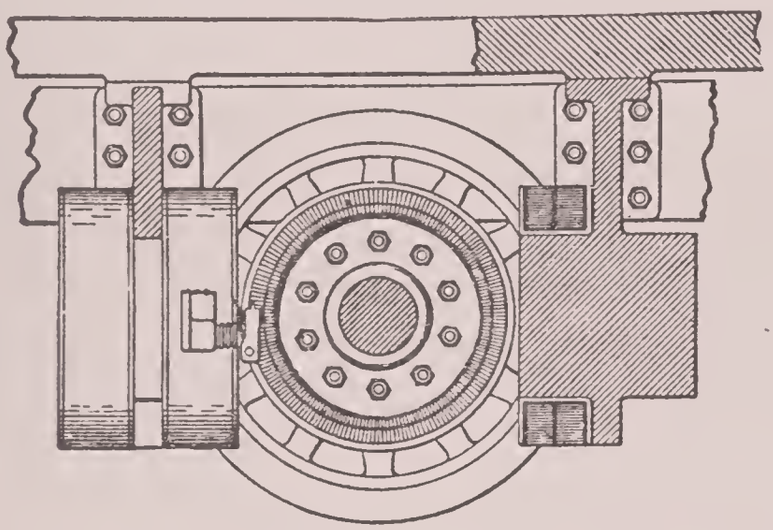


Fig. 427. Locomotive Motor.

This bar shown in Fig. 428 runs the length of the four motors.

In Fig. 427 the broad piece below the bar is the locomotive frame which together with the transoms acts as the main magnetic circuit. The transoms are bolted to the frame as shown.

The five transoms in the middle of the frame carry

bosses which serve as magnet cores and the field coils are placed on them.

The pole face not shown in Fig. 427, but in Fig. 428, is of soft iron sheets held between two heavier end pieces, dove-tailed to the magnet core and keyed. These prevent the field coils from slipping off.

The ordinary motor has a cylindrical pole face, but these are almost flat, so that the armature can stay still on the track and the frame with the poles swing up and

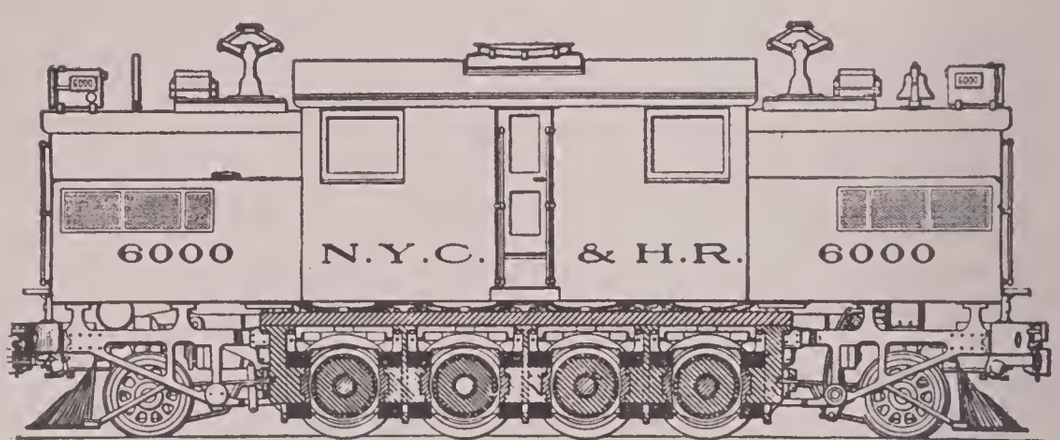


Fig. 428. The First New York Central Locomotive.

down without striking the armature. This shape also makes it possible to drop an armature down into a pit without disturbing the pole faces or field coils.

The brush holders being on the transoms, move up and down with the frame, being kept in contact with the commutator by springs.

The collector shoes are also fastened to the frame, being kept on the third rail by springs.

The field coils are 80 turns of copper ribbon 3 inches

wide insulated by card board. They are wound on a brass spool which is slipped into a shell and the protection completed by riveting the joints and pouring shell full of a bituminous compound.

The journal bearings each have a pedestal resting on them which carries on its upper end a half elliptic spring. The bearings slide in jaws of the frame.

The weight of each pair of drivers, the axle, the complete armature, journal bearing, pedestal and spring rest solidly on the track. The two trucks do the same.

Everything else rests on the frame, and the frame is hung from the springs.

The two trucks and the drivers furnish six axles to support the weight of frame and its load.

Equalizing levers distribute the load properly, and cross equalizers give a three-point support.

The superstructure consists of the cab in the center and two end compartments.

In the center of the cab stands the steam heating apparatus. A kerosene automobile burner heats a coil tube boiler, producing superheated steam. This when passed through a reducing valve furnishes to the train absolutely dry low pressure steam. In this way the size of plant capable of heating a train is reduced to a minimum. The fuel and water pumps are motor driven.

At one end of this heater is the motor driven air compressor. There are two motors on its shaft connected in series. This gives 300 volts per motor and enables them to run at the low speed of 175 R. P. M. The compressor supplies 130 lbs. of air for braking, whistling, bell ringing and sanding. It is regulated by a starting

and stopping switch which is opened and closed by an electro magnet. This magnet is operated by switch opened and closed by the action of the air on a diaphragm. 125 lbs. pressure starts and 135 lbs. stops the motors.

At both corners diagonally opposite are duplicate sets of controlling apparatus. They consist of the controller bar and reverse lever under left hand. In front are the automatic and straight air brakes, the hand sander, the

Fig. 429. Motor Armature.

ammeter and air gauge, and the control circuit switch. At the right hand is the air blast sander, bell and whistle valves.

The end compartments contain a central aisle and on either side in asbestos lined sheet steel cabinets are contained the other apparatus of the control.

Each of these four (two at each end) cabinets contains the resistances and the contactors for one motor. Evenly

distributed among the four are the two reversers, the main power switch, the circuit breaker, the throttle relay, air pressure governor, air sanders, and the contactors for motor combinations.

The lighting and head light switches are in the aisles for ready access.

A view of a complete armature mounted on driving axle is given in Fig. 429.

The locomotive is fitted with the Sprague-General Electric Type M Control with a controlled acceleration.

There is a friction clutch attached to the main shaft of the controller, operated by a magnet. This magnet is in the circuit of wire 18 which also contains a magnetically operated switch.

The operating coil of the switch is a part of the main power circuit leading to motor No. 2.

When the motor is taking less than 900 amperes from the line the magnet is too weak to close the switch, and so the locking coil is not energized, and the controller handle is free to be moved.

Should the motor current rise above 900 amperes the magnet closes the switch, the lock coil throws the clutch and the engineer can not advance the handle until the current falls to its normal value.

Fig. 430 shows the wiring of the four motors, their resistances and contactors as arranged in the New York Central locomotive No. 6000, the first one built.

The terminals marked T are connected to the third rail or "trolley," those marked R to the rails or return circuit, often called "ground."

The armatures are represented by circles and the fields by squares. The resistances are shown by the crooked

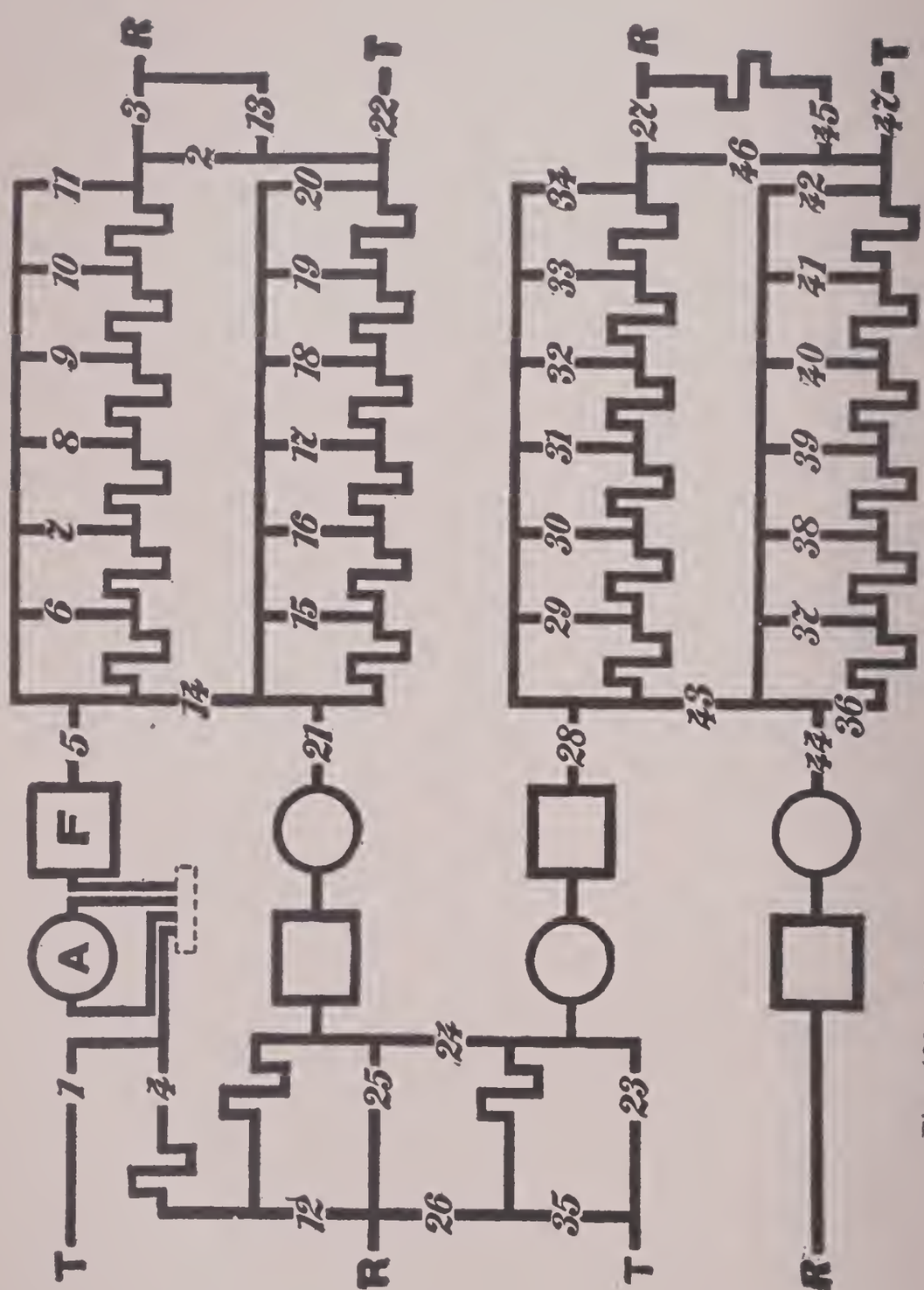


Fig. 430. Diagram of Motor Control New York Central Locomotive.

lines, being a rough imitation of the shape of the cast iron grids used as resistances.

On No. 1 motor at the top has been indicated how the leads go to a reverser, but this has been omitted from the rest of the diagram for the sake of clearness.

Each number represents a *contactor* and when the contactor is closed the gap in the circuit as shown in the diagram is closed and current is permitted to pass.

The wiring which actuates these contactors is called the *control system* and will be the subject of another illustration. This diagram (Fig. 430) only shows the main or power circuits. Each wire in the *control* is numbered and this number is used to refer to it.

The controller which actuates these 47 contactors has 24 positions or *notches* numbered consecutively. Nos. 10, 17 and 24 are running positions, placing the motors at N 10 all in series; at N17 in series-multiple i. e., two in series and two in parallel or multiple; at 24 all in multiple. This gives quarter, half, and full speeds. At all the other notches there is more or less resistance in the circuits, and the controller must not be left permanently at any notch but these three.

The motors are numbered from the top of Fig. 430 down, Nos. 1, 2, 3 and 4. The numbers 1, 2, 3 and 4 after a symbol denote the motor to which the part belongs.

F 1 denotes the field of motor No. 1. R 12 denotes the second resistance (counting from left to right) of the first motor. R 36 denotes last resistance of third motor.

Each motor has a set of six resistance grids whose total for each motor is 0.4 ohm and whose parts have resistances as given in Table A. In Table B is given the resistance left in each motor circuit when the previous grids are cut out.

TABLE A.

Resistance	1=0.120	ohm.
Resistance	2=0.085	ohm.
Resistance	3=0.055	ohm.
Resistance	4=0.050	ohm.
Resistance	5=0.046	ohm.
Resistance	6=0.044	ohm.

TABLE B.

Resistance	1 to end=0.40		ohm.
Resistance	2 to end=0.28		ohm.
Resistance	3 to end=0.195		ohm.
Resistance	4 to end=0.14		ohm.
Resistance	5 to end=0.09		ohm.
Resistance	6 to end=0.044		ohm.

There are four other resistances, one per motor, located as follows:

B 1 between contactor 4 and R.
B 2 between F 2 and 12.
B 3 between A 3 and 35.
B 4 between 45 and R.

These resistances are 0.48 ohm. each. B 2 and B 3 are used as *bridge* resistances to prevent short circuits when changing from slow to middle speed. B 1 and B 4 are used as resistances during electrical braking.

Fig. 431 shows the electrical connections of a locomotive reverser.

The right and left sides are exact duplicates, so only one side will be described.

As shown the S portion of the reverser is shut and the O part is open. The magnets and link bars operating the two pairs of toggles S and O are left out, in order to make diagram simpler.

T represents a tap from the main power cable and may be considered as *"trolley."*

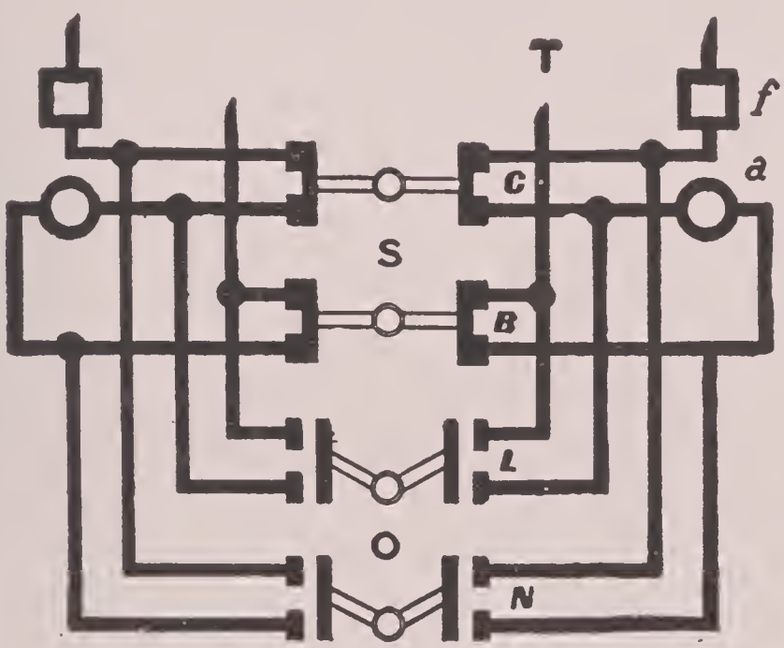


Fig. 431. Diagram of Locomotive Reverser.

The current comes from T goes through B to the armature *a* (circle), thence to C and passes through the field *F* (square). The same thing happens on the other side of S.

If, however, the magnet connected to O is energized, the toggles O will straighten and close the contacts L and N on both sides. The magnet S being interlocked with O is now de-energized and the S toggles loosen and contacts C and B open.

Then the current goes from T to L and through the armature in *opposite* direction than before, thence to N

and through the field in the *same* direction as before. The motor now reverses; for to reverse a motor, reverse the armature or field but not both.

Operation of Control.

Imagine the engineer standing in the cab with the reversing and air wrenches in his hand. The controller levers are not removable and are both in place in the *off* position. In fact they had to be there before the reversing wrench could be removed, and the air brake wrench had to be at lap before it could be taken off. There is but one reverse and one air wrench per locomotive.

He seats himself, puts on the two wrenches and throws the reverse wrench to forward. This puts wire 8 to trolley and ground (T. and R.), and the control current passes through the reverser magnets and pulls both to the forward position.

Wires 51 and 52 now close contactors 1-5-21 and 28-44-36. These are *always* closed while the locomotive is running.

Notch 1 now energizes W 1, closing C 2-24-46, completing a series circuit of the four motors and 1.6 ohms resistance.

For the next nine notches these contactors remain closed and in addition contactors close and open as follows:

Notch 2 energizes W 6, closing C 20, cutting out all of the resistance belonging to M 2 thus reducing the total resistance to 1.2 ohms.*

---

*By this I mean the **extra** resistance in grids is 1.2 ohms. The resistance of the motors is always present and need not be mentioned each time.

Notch 3 energized W 7, which picks up C 20 (which W 6 no longer holds) and also C 42, which cuts out 0.4 ohms more, reducing resistance to 0.8 ohms.

Notch 4 energizes W 10 which holds up C 20 and 42 and also closes C 34 cutting out 0.4 ohms more.

Notches 5-6-7-8-9: While W10 continues to be energized holding C 20-34-42, wires 11-12-13-14-15 are successively energized closing C 6-7-8-9-10 one after the other. Thus gradually reducing the resistance from 0.4 to 0.044 ohms as shown by Table B. Each contactor stays down until the following one closes.

Notch 10: Wire 16 is energized and W 10 de-energized but C 20-34-42 are held up by W 16 and it picks up C 11 in addition, thus putting the motors in full series between Trolley 1 and Return 4, without resistance. N 10 is a running position at a slow speed.

In moving from N 10 to N 11 many changes occur. W 51 and 52 are of course still working. W 5 cuts in and transfers C 2 and 46 from W 1 to itself, it also closes C 12 and 35. The two bridging resistances B 2 and B 3 being together equal to 0.96 ohms prevent a short circuit from T 3 to R 2.

The circuit containing B 2 is called a *bridge* because it bridges over what would otherwise be an opening in the circuit as the changes occur.

W 1 now drops out of circuit allowing C 24 to open, thus placing two motors in series between T and R.

W 2 now is energized and closes C 25 and 23 cutting out B 2 and B 3 considerably reducing the resistance of each motor combination.

W 10 now closes C 20 and 42 but *not* C 34 as it did before. W 10 can only shut C 34 if C 24 is already closed.

This is due to a system of interlocks. C 24 is now open, for it dropped when we shifted from W 1 to W 5.

The motors are now in series—multiple with half of the resistance in series.

Notches 12 to 17 (both inclusive) energize in succession W 11-12-13-14-15-16 closing C 6 and 29, then C 7 and 30, etc., thus stepping out the remaining resistance until at N 17 we are at a free running position with no resistance in.

Between N 17 and 18 we shift from W 2 to W 3 which performs same duties as W 2 and in addition closes the bridges C 14 and 43. These two contactors produce no electrical changes for the resistances were already cut out entirely by W 16 through the contactors under its control.

W 16 can now be and is dropped without any electrical change. W 4 is now energized closing C 3-22-27-47. There are no short circuits caused because between trolley and return on one side of bridges are the motors and on the other side are the double resistances, each 0.8 ohms.

W 2 is again taken up which takes care of C 24-25 holding them up and W 2 is dropped, letting go of C 14 and 43.

We are now in multiple with resistance in series.

Notches 19 to 24 keep W 2 and 4 energized and successively energize W 11-12-13-14-15-16, closing contactors four at a time, i. e., C 6-15-29-37 then C 7-16-30-38, etc., until finally W 2-4-51-52 and 16 keep the contactors closed for free full multiple running.

The spaces between N 10 and 11; N 17 and 18 are wider than the others to give room for enough motion to make the desired wire changes. These spaces must be passed over by a continuous motion of the controller arm.

Wires 11 to 16 always close contactors four at a time but the first and second times they are used part of the contactors closed produced no electrical changes and for simplicity mention of the fact was omitted.

Contactors 4-26-13-45 are used when braking electrically in this way.

A switch called a commutating switch is thrown and the controller pulled to first notch.

The commutating switch brings in wires 17-4 and 5, W 17 closes contactors 4-13-26-45.

W 4 and W 5 due to interlocks do not close as many contactors as they would if energized through main controller so W 4 only closes 3-27 and W 5 only closes 12.

Notch 1 of controller energizes W 51 and W 52. W 52 as usual closes 28-36-44 while W 51 on account of interlocks only closes 5 and 21. The four motors are now in parallel across the track rails all connection with third rail being cut off. They now act as generators and act as brakes.

This can only be done when one locomotive is on a train else the other locomotive being so near (40 feet) acts as a short circuit.

The one wire not mentioned W 18 is the one called controller lock. It energizes the magnet of the friction clutch through a relay whenever current input exceeds 900 amperes per motor.

Table C gives the number of the control wire, the contactors operated by it, and the notches of the controller making use of the wire.

In this table and elsewhere 1 to 10 means both inclusive and 1-2-10 means separate numbers.

TABLE C.

Notches.	Wires in circuit.	Contactors closed.
All	51	1-5-21
All	52	28-36-44
1 to 10	1	2-24-46
2	6	20
3	7	20-42
4 to 9	10	20-42-34
11 to 16	10 (interlock)	20-42
5-12-19	11	6-15-29-37
6-13-20	12	7-16-30-38
7-14-21	13	8-17-31-39
8-15-22	14	9-18-32-40
9-16-23	15	10-19-33-41
10-17-24	16	11-20-34-42
11 to 17 18 to 24	2	25-23
11 to 17	5	12-35-2-46
Between 17 & 18	3	14-43-25-23
18 to 24	4	3-22-27-47

Reverse lever.

Forward.....8		Reverser forward.
Backward.....0		Reverser backward.
Braking	17	4-13-26-45
Braking	51-(Interlock)	5-21
Braking	52	44-36-28
Braking	4-(Interlock)	3-27
Braking	5-(Interlock)	12
Trolley wire	18	Controller lock coil.

This table will enable you to find what groups of contactors go into operation at same time.

It being found that electrical braking when two locomotives were being operated was useless it was cut out of the equipments delivered to the Central.

Changes in the numbering of the contactors were also made, but the method of control is the same. This lesson will enable the student to get information from the wiring diagram given in connection with the catechism on the locomotives.

LESSON 43.

Rolling Stock.

The electric locomotive as a slow speed, heavy load tractor is quite old and there are many of them doing good service to-day that were built ten years ago.

Fig. 432 is in use by the American Bridge Co. Fig. 433 is used in the works of the Westinghouse Electric Co. Fig. 434 is in use in a lumber mill. Fig. 435 is used to haul scrap and pig iron. Fig. 436 is used by the Maryland Steel Co. to haul ingots and moulds. Fig. 437 is in use in Hawaiian Islands.

Fig. 432. 10,000-Pound Locomotive.

Fig. 438 shows how standard motors can be adopted to narrow gauge locomotive.

Figs. 439, 440 and 441 show conventional types of higher speed locomotives the latter showing the use of two trolleys allowing the collection of larger currents

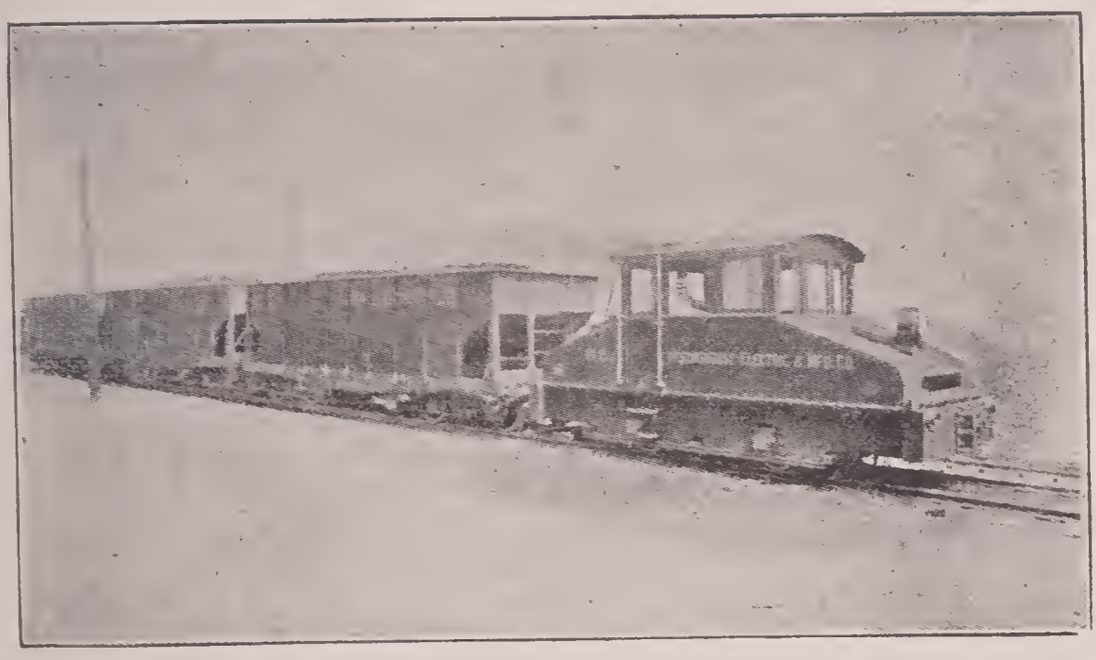


Fig. 433. 95,000-Pound Locomotive.

Fig. 434. 2,600-Pound Locomotive.

without too great a resistance and sparking at trolley wheel.

Fig. 442 shows a 560 H. P. locomotive operating along the Hudson River steamship wharfs. Gear reduction is 3:1. It makes 8 miles an hour.

Fig. 435. 8,000-Pound Locomotive.

Fig. 443 shows an American locomotive operating in the Austerlitz Station of the Paris-Orlean R. R. The same locomtives also haul 160 ton trains under Paris in a tunnel to the Quai d'Orsay terminal.

Fig. 436. 10,000-Pound Locomotive.

Fig. 437. 19,000-Pound Locomotive.

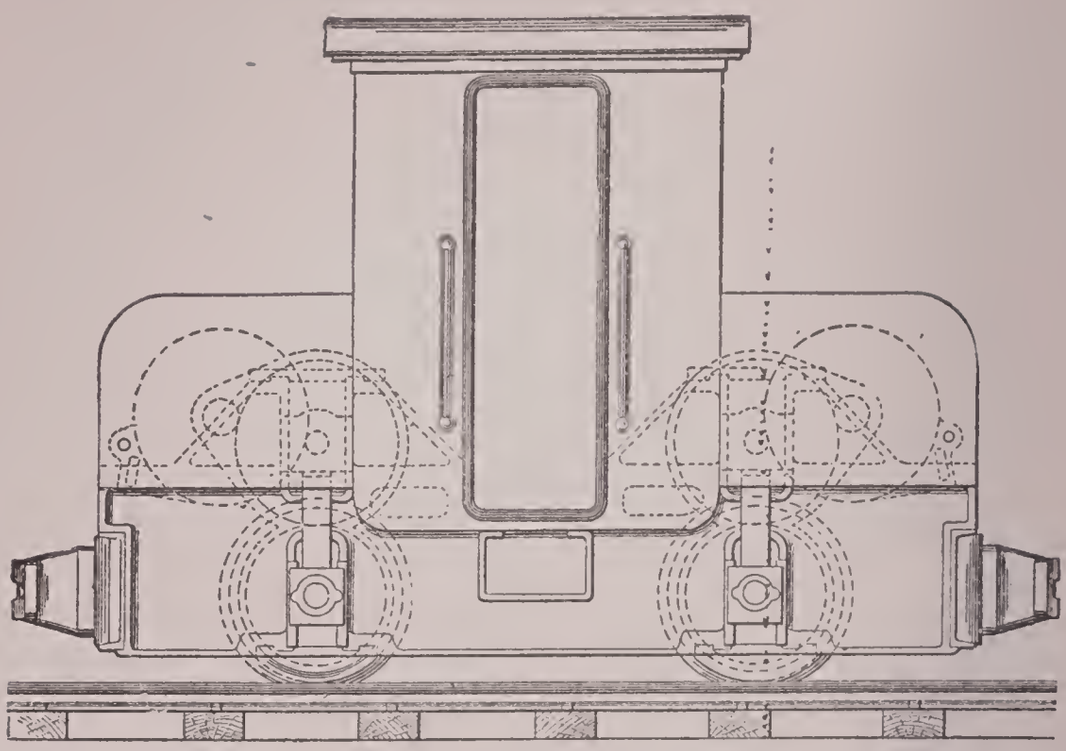


Fig. 438. Special Design for Using Very Large Motors on Narrow Gauge Track.

Fig. 439. 45,000-Pound Locomotive.

Fig. 444 shows the locomotive of the Buffalo & Lockport R. R., designed to handle freight and passenger service between these stations. They are equipped with motors capable of developing 600 H. P. Owing to slow speeds required (15 miles per hour) the motors are connected two in series permanently. They start with all

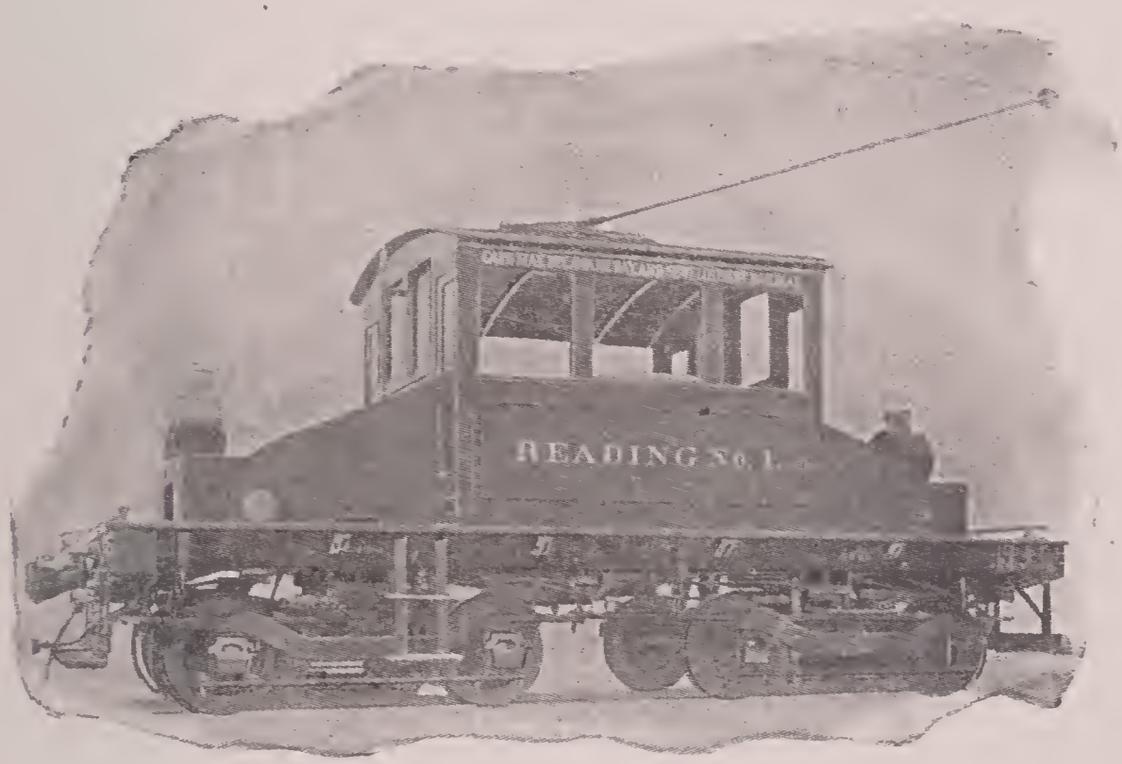


Fig. 440. 47,000-Pound Locomotive.

four in series and then place them in series parallel. They draw 500 amperes while accelerating a 450 ton train up to 14 miles an hour.

Fig. 445 shows a locomotive used in factory yard to drill freight cars.

The Baltimore & Ohio R. R. has been using 87 ton electric locomotives to haul its steam trains (locomotive and all) through the tunnel under the city of Baltimore.

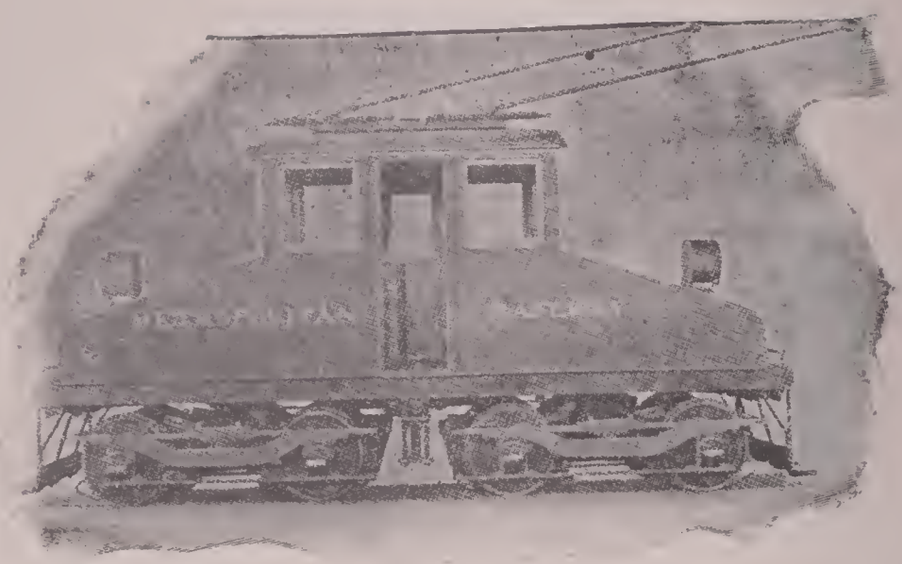


Fig. 441. 55,000-Pound Locomotive.

Fig. 442. Steamship Connecting R. R. Draw-Bar Pull at 8 M. P. H. 10,000 Pounds.

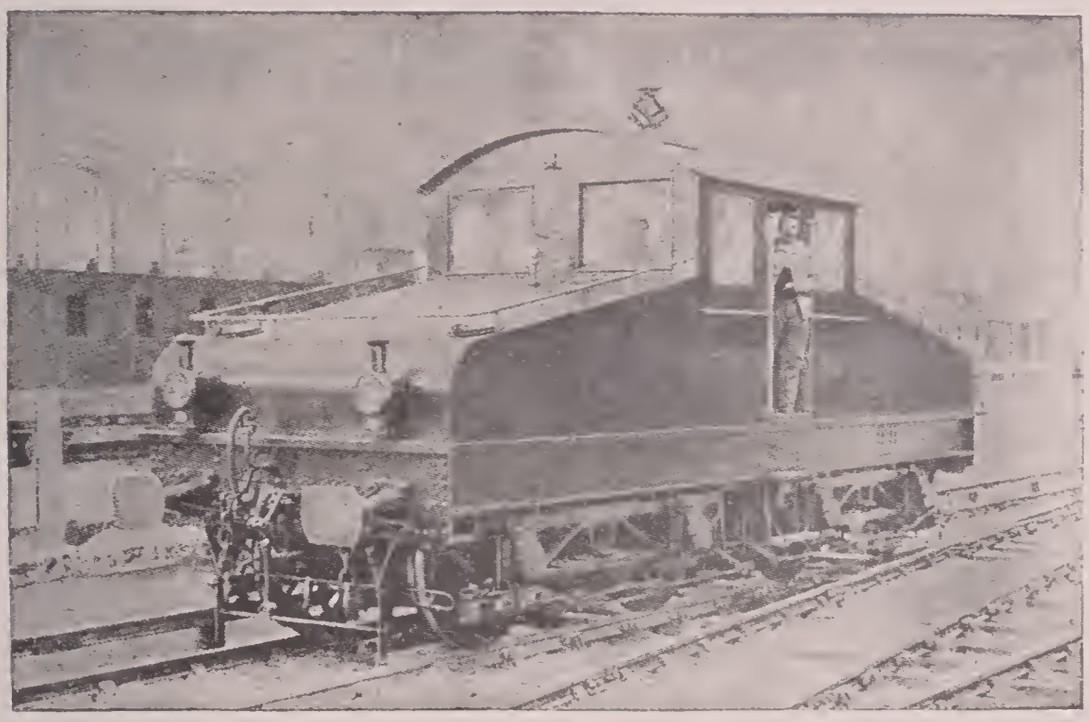


Fig. 443. Electric Locomotive at Austerlitz Station. Paris and Orleans R. R.

Fig. 444. Buffalo and Lockport Locomotive.

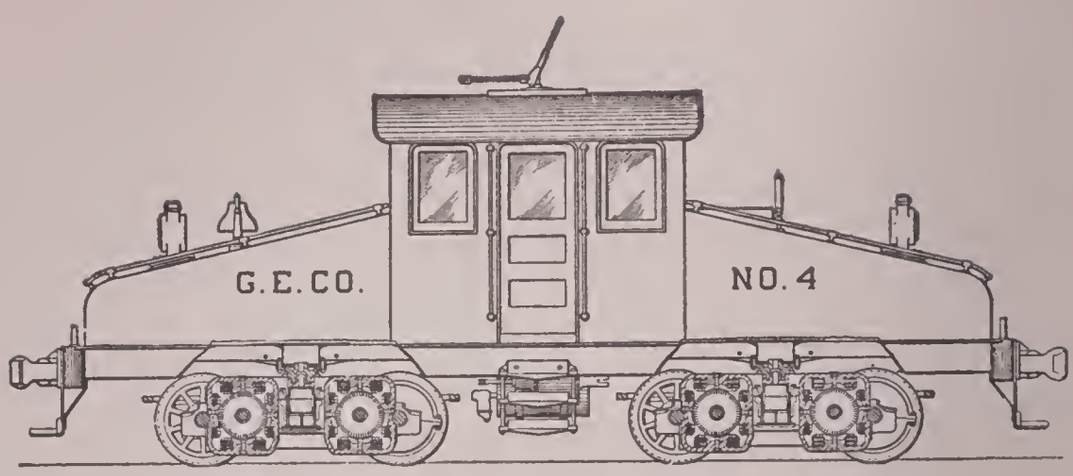


Fig. 445. Factory Yard Locomotive.

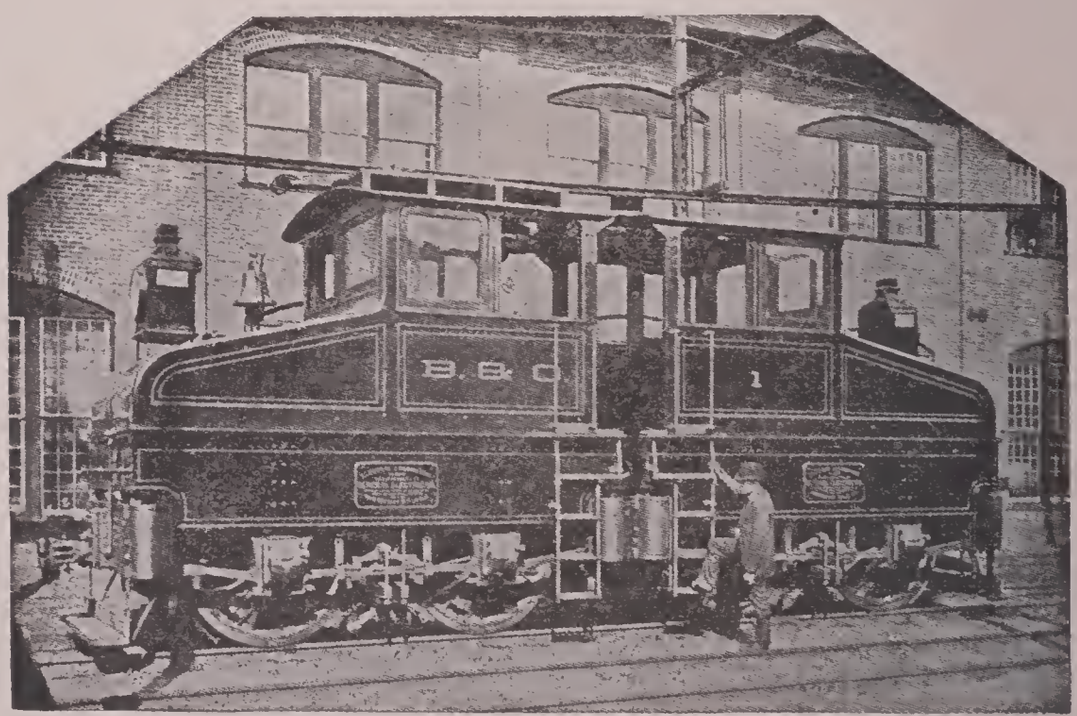


Fig. 446. B. & O. Gearless Locomotive.

One of these locomotives is shown in Fig. 446. Three we put in service in 1896 and for ten years have given good service: They will each haul a 2300 ton freight at 10 miles an hour, or a 500 ton passenger train at 35 miles an hour. They draw 2200 amperes at 625 volts during acceleration, dropping to 1800 at full speed.

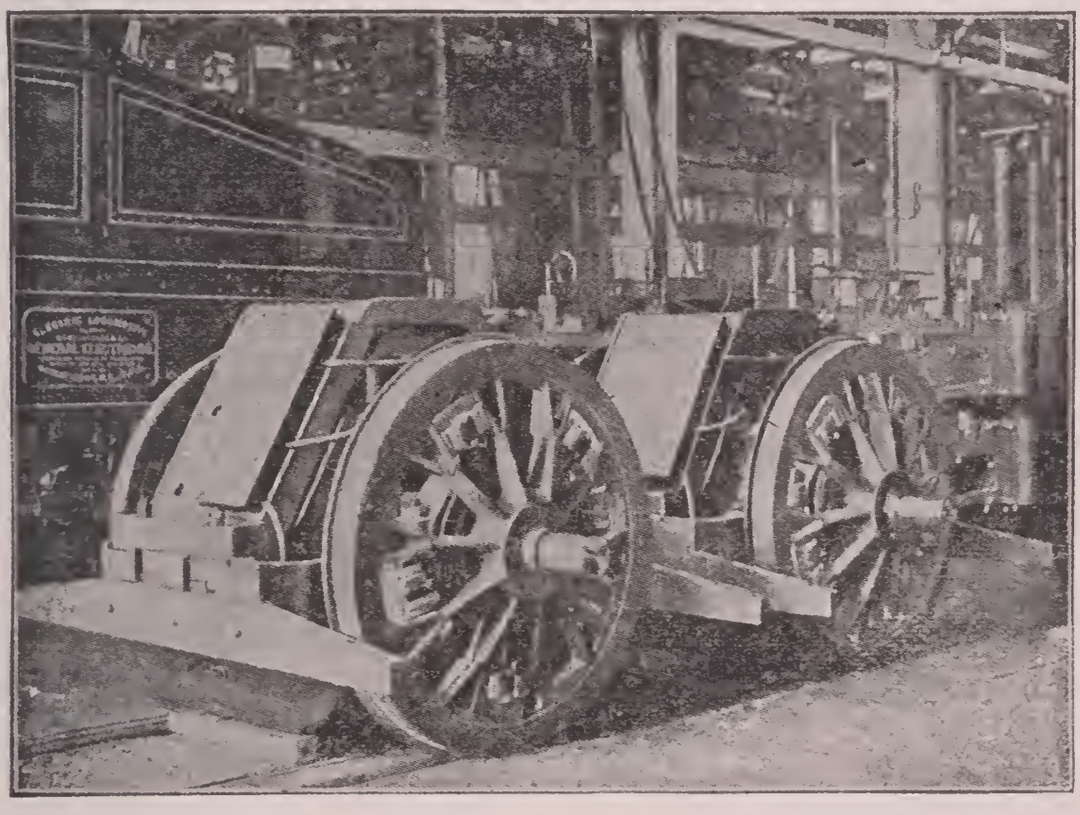


Fig. 447a. B. & O. Locomotive Truck.

One of the two trucks is shown in Fig. 447. The motors are six pole and connected directly to axle. There are two motors in each truck making four in all.

In 1903 the B. & O. put in service two more locomotives. Each one is composed of two units. Each unit contains four motors, each geared to one of the axles by a 4:1 gear. The motors are 4 pole. Each unit weighs 73

tons. Thus the whole locomotive of 146 tons has 1600 horse power.

The geared type is perhaps best for such slow speed work.

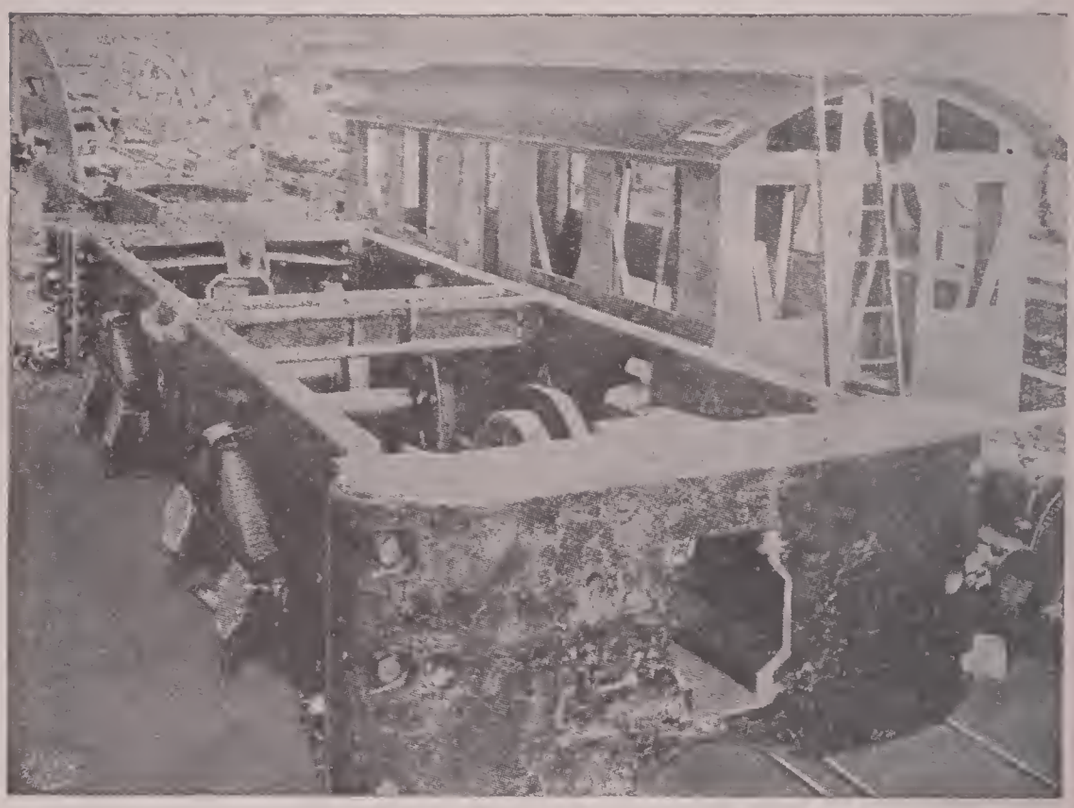


Fig. 447b. B. & O. Locomotive Frame and Cab.

The freight locomotive of to-day will be a 16 wheel locomotive of the 0-16-0 type with a joint in the center of its frame like a Mallet Compound. This is called an articulated frame.

Each axle will have its motor. Its general dimensions are shown in Fig. 448.

A New York Central locomotive drawing a train is shown in Fig. 449.

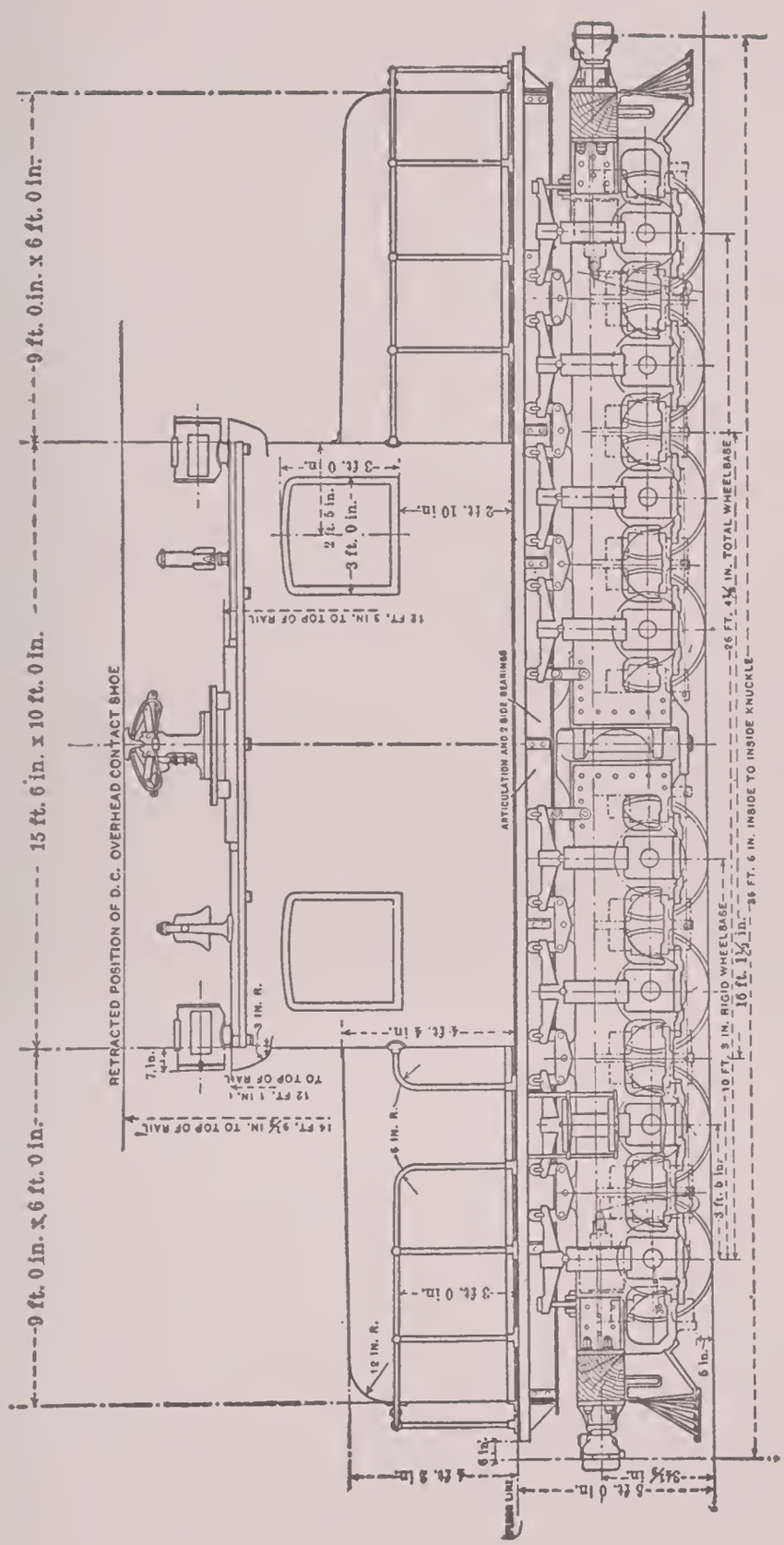

9 ft. 0 in. x 6 ft. 0 in.
15 ft. 6 in. x 10 ft. 0 in.
9 ft. 0 in. x 6 ft. 0 in.
RETRACTED POSITION OF D.C. OVERHEAD CONTACT SHOE
ARTICULATION AND 2 SIDE BEARINGS
26 FT. 4½ IN. TOTAL WHEELBASE
10 FT. 3 IN. RIGID WHEELBASE
16 ft. 1½ in.
36 FT. 6 IN. INSIDE TO INSIDE KNUCKLE
12 FT. 3 IN. TO TOP OF RAIL
14 FT. 9½ IN. TO TOP OF RAIL
12 FT. 1 IN. TO TOP OF RAIL
3 ft. 0 in.
2 ft. 10 in.
2 ft. 6 in.
3 ft. 0 in.
4 ft. 4 in.
3 ft. 0 in.
3 ft. 6 in.
5 ft. 0 in.
3 IN. R.
6 IN. R.
12 IN. R.
7 in.
6 in.
6 in.
34½ in.

Fig. 448. Typical Freight Locomotive of 0-8-8-0 Type.

Fire proof cars are a very valuable asset to a road, as a means of gaining public favor and their actual calming influence in case of not only slight fires due to electrical troubles but also in slight collisions. Figs. 450 and 451 show a fire proof car designed by Mr. Gibbs. The Erie railroad is using similar ones for Postal Service. The Interborough Co. is using the Gibbs car for motor cars.

Fig. 449. New York Central Locomotive with Train.

These are finished inside with dark green enamel and aluminum paint which although a little hard looking makes a good appearance.

Fig. 452 shows a train on the West Shore R. R. operating between Utica and Syracuse.

Fig. 453 shows a locomotive and Fig. 454 a motor car of the Valtellina Rail Road of Italy. This is a 3 phase equipment.

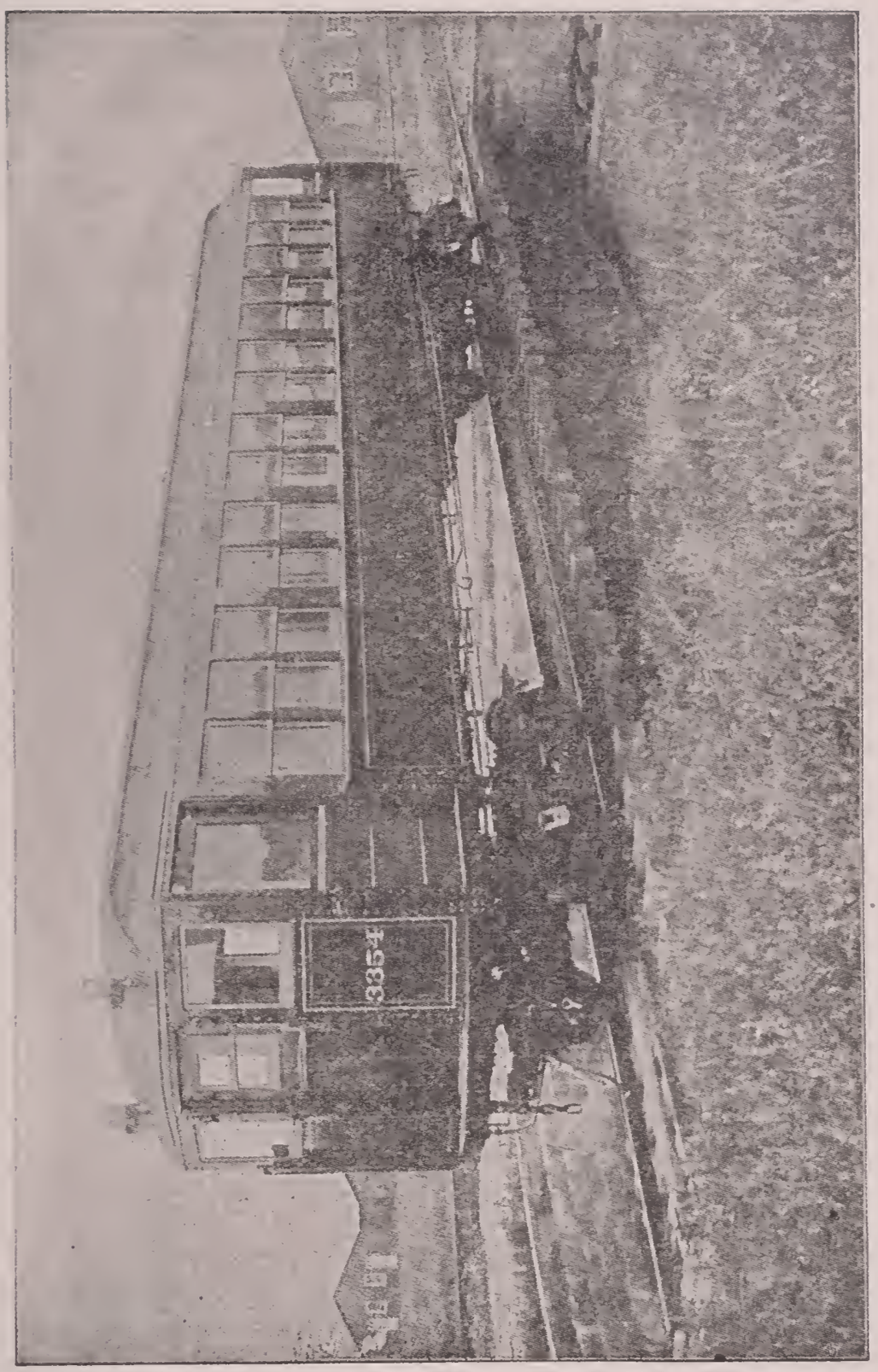


Fig. 450. Gibbs' Fire-Proof Car. Long Island R. R. and New York Subway.

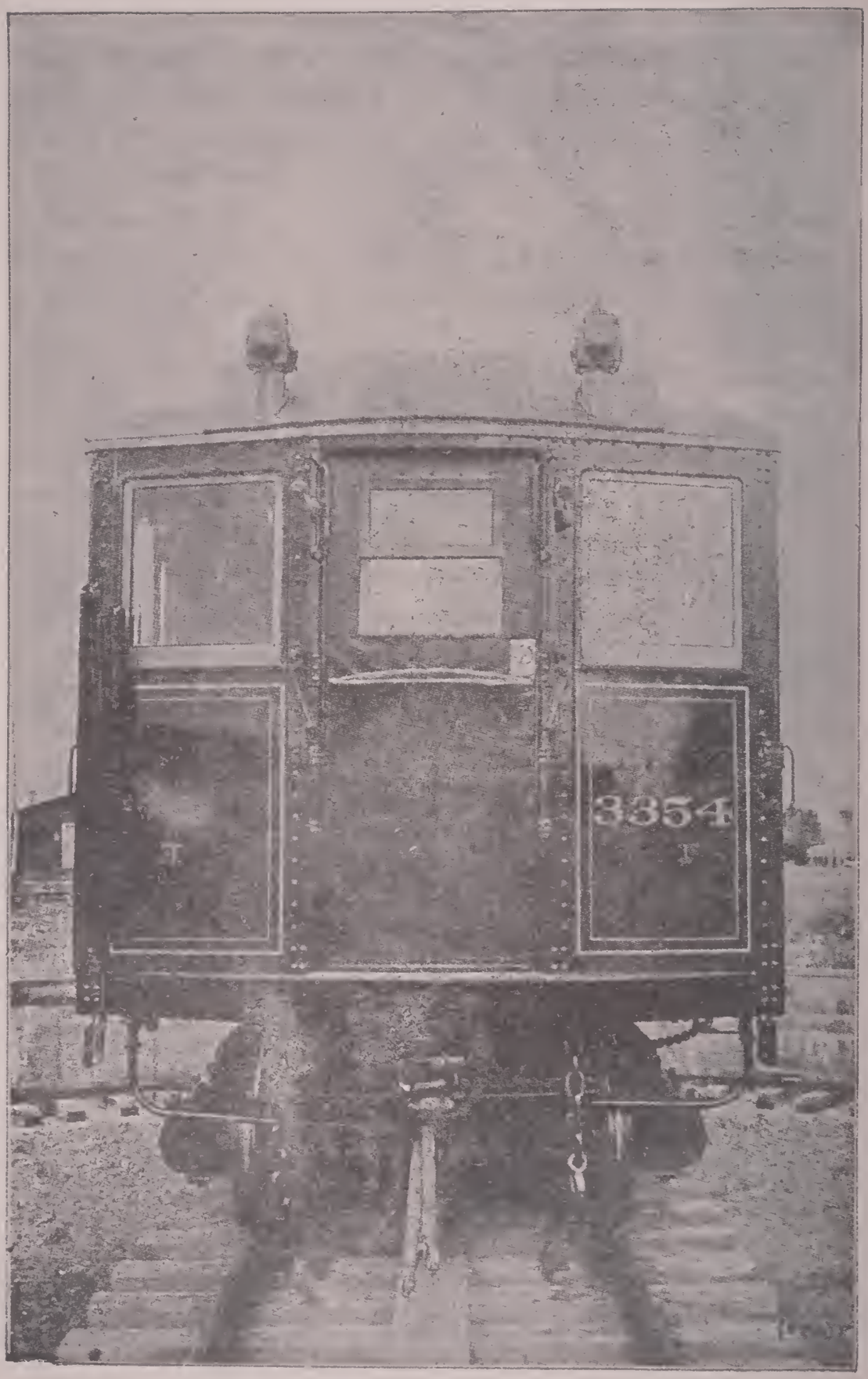


Fig. 451. End View of Fire-Proof Car.

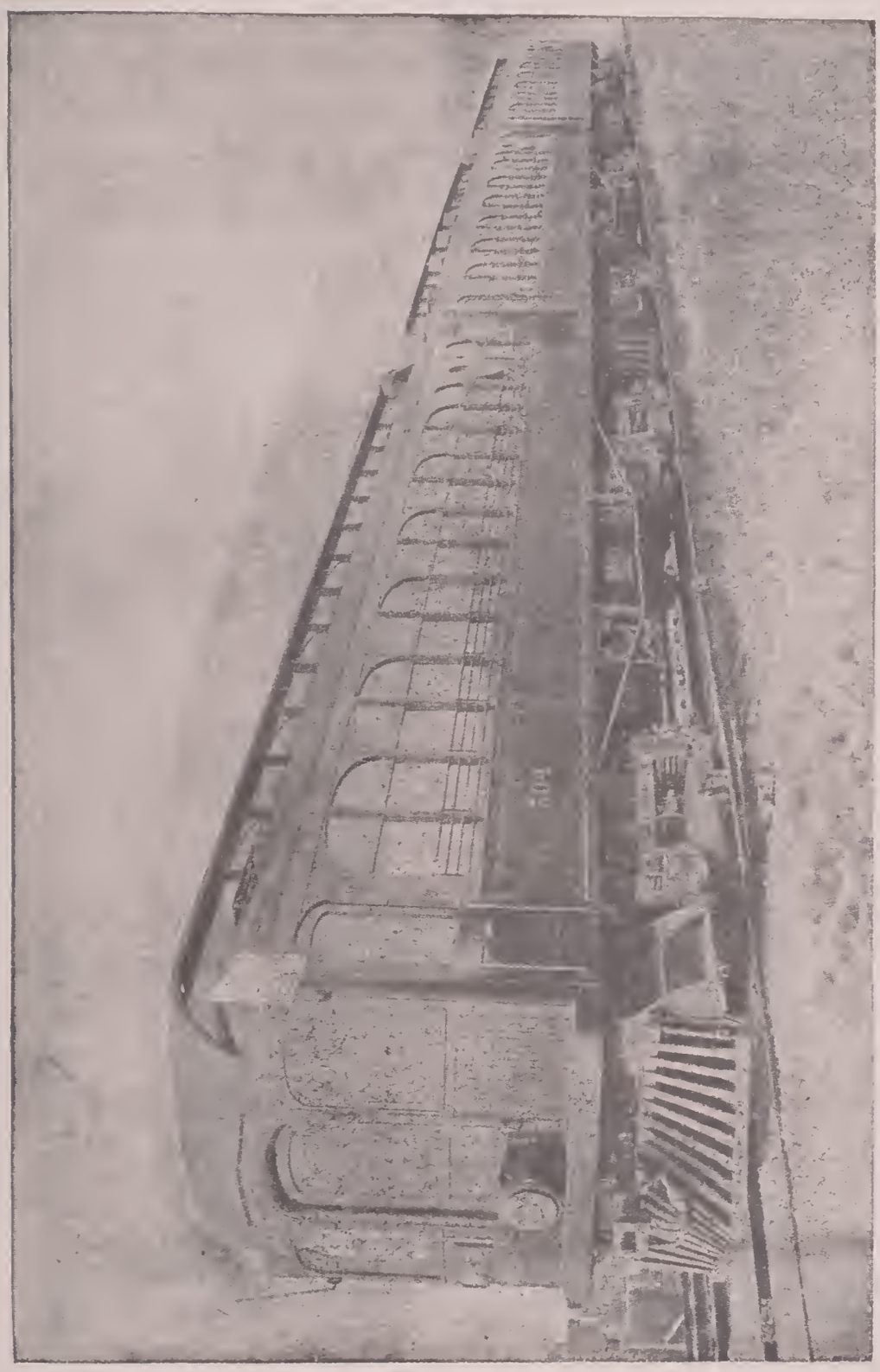


Fig. 452. West Shore Motor Car Train.

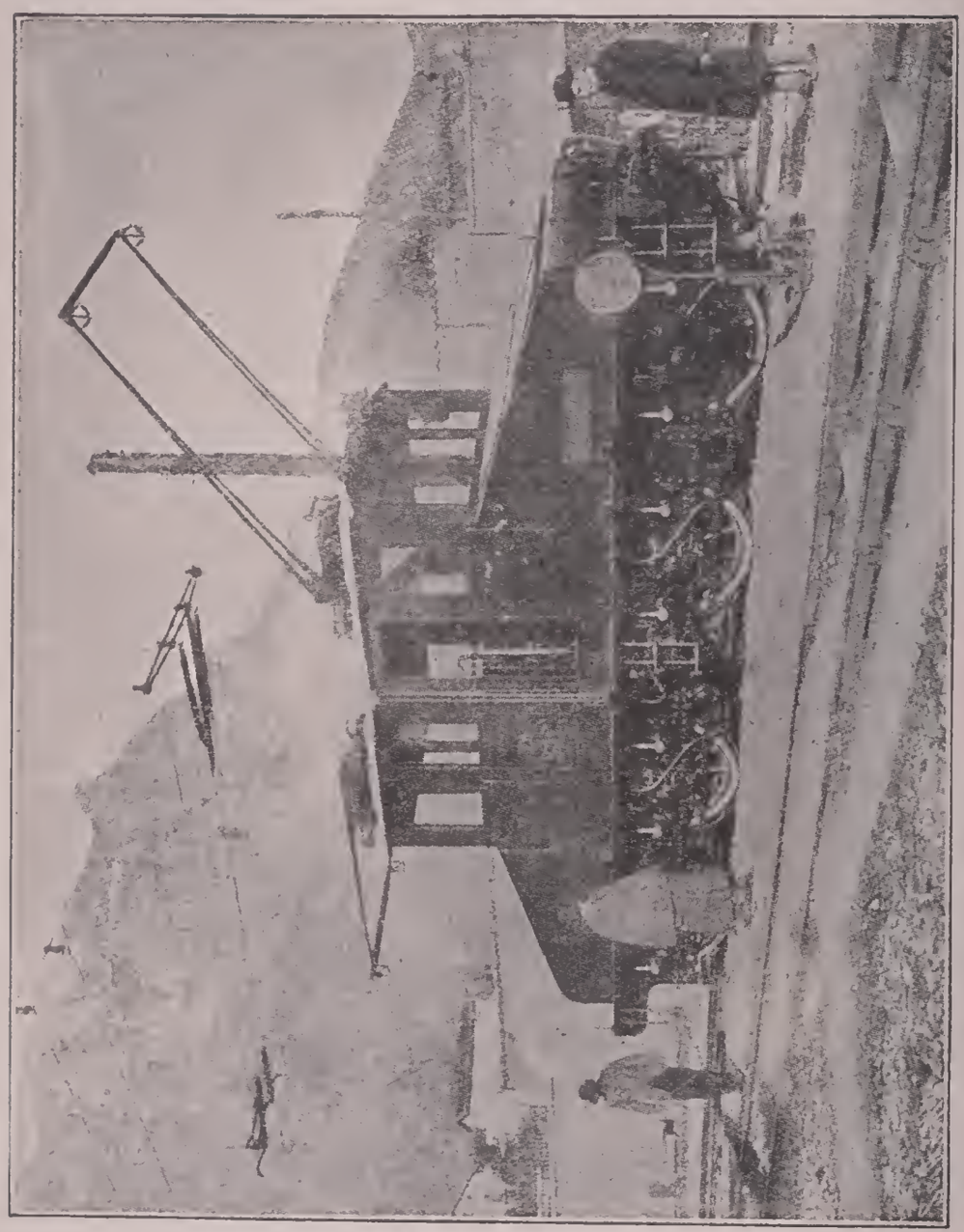


Fig. 453. Valtellina Three-Phase Locomotive.

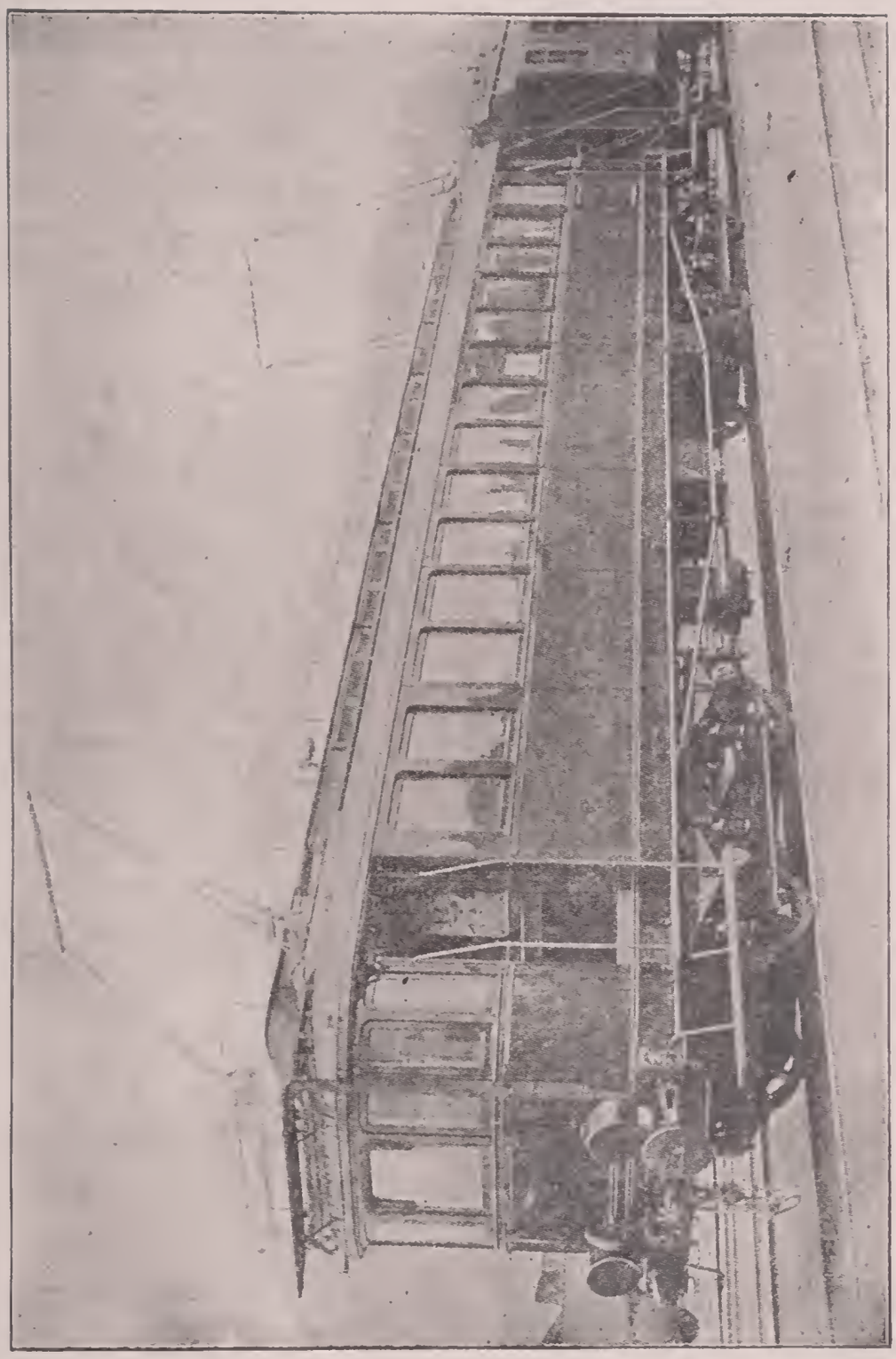


Fig. 454. Valtellina Three-Phase Motor Car.

Trucks.

While the size of motors has been limited by the gauge of the rails, yet the demand for larger horse powers has influenced truck builders to put 36 inch wheels on the motor trucks. Such trucks will soon be standard for steam road work. The trailer truck at other end of car will have 33 inch wheels as standard.

Fig. 455 shows the general dimensions of a motor made for a 33 inch wheel truck. It will be noticed that the car axle goes through a set of bearings on the side of the motor frame. The large gear is fastened to the car. The motor shaft runs in bearings at either end of the frame. The pinion on motor shaft engages with gear on car axle.

Some of the weight of motor is given to car axle by the bearings in motor frame through which this axle passes. The rest is transferred through the truck frame.

Any motion of the motor must be in a circular arc around the car axle as a center, for the distance between center of car axle and motor shaft must always be same, else gear teeth will bind.

The Master Car Builders Association has given its sanction to certain constructions which are familiarly known by the initials, M. C. B.

A truck called the "M. C. B. equalizing truck" is shown in Fig. 456. The center pin is shown on center transom with bearing plates on either side. Outside of these are the side bearings to catch the weight when car rolls. Any up and down motion due to compressing the springs should not bring side bearing plates into contact. They generally come into contact when rounding curves, and to prevent interference with swiveling of trucks under

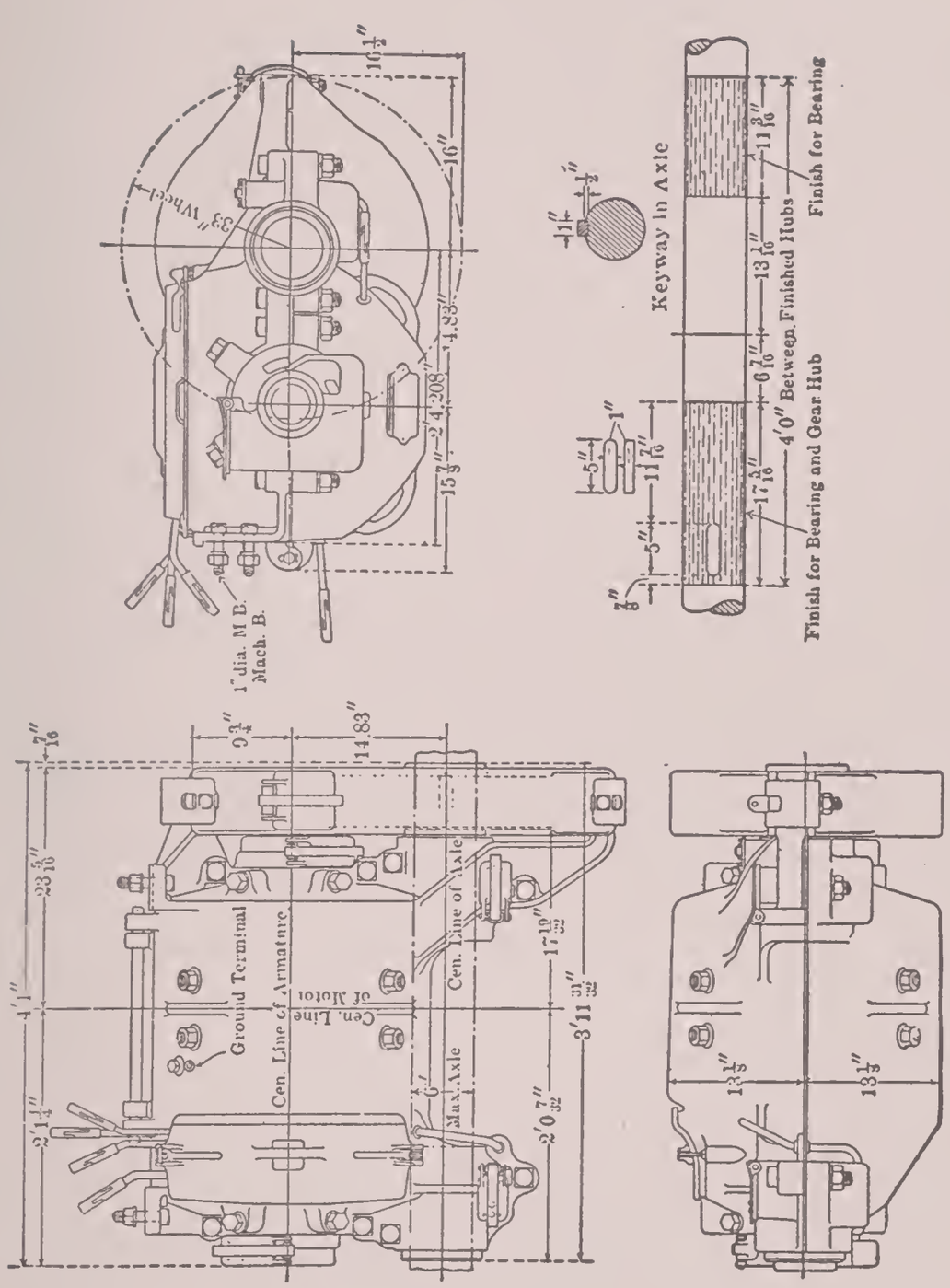


Fig. 455. General Dimensions of Railway Motor.

these circumstances, these bearings are frequently made with rollers.

In the plan view of Fig. 456 only one motor is shown to give a clearer view of the motor suspension. A rec-

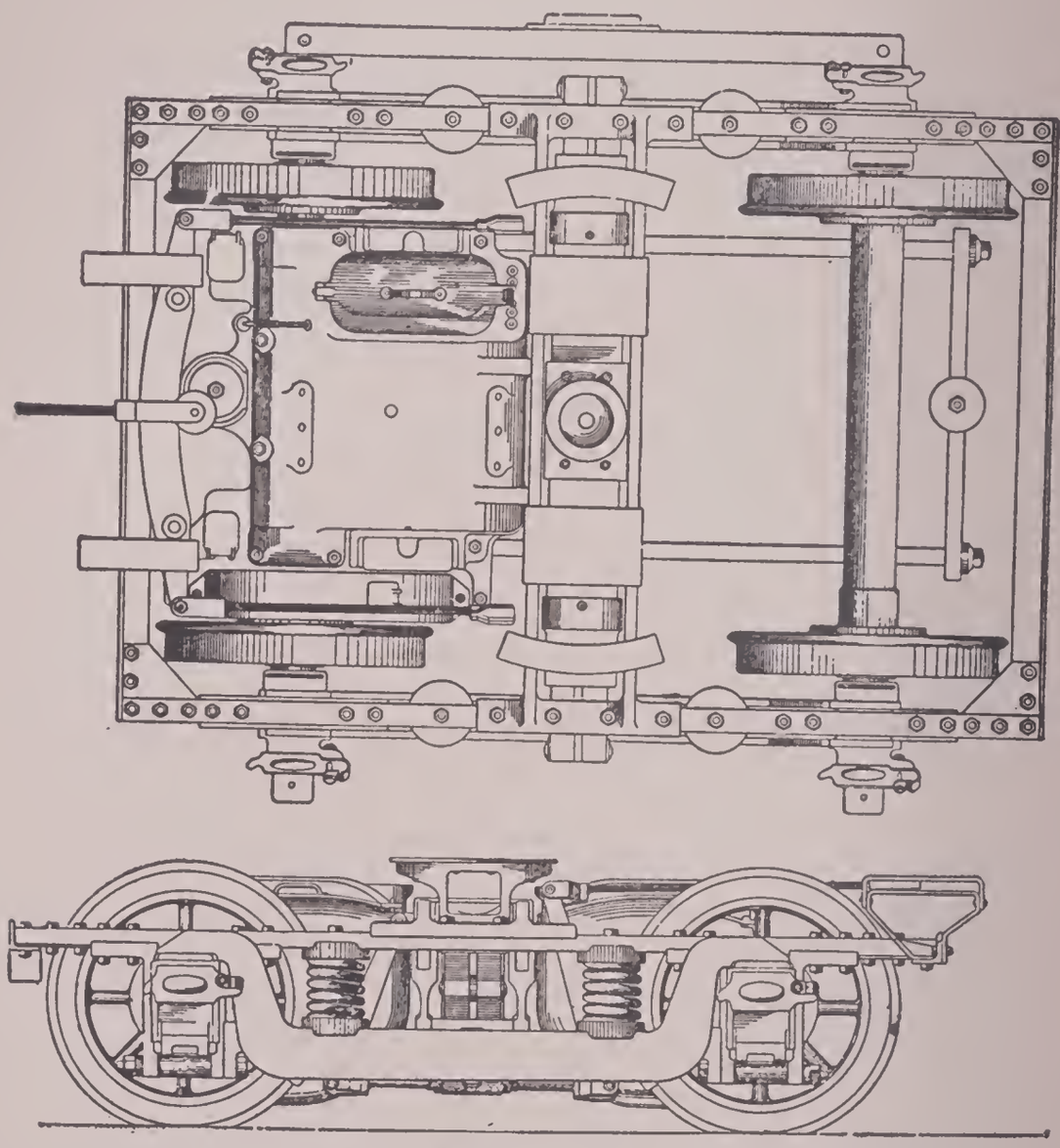


Fig. 456. M. C. B. Electric Truck. Cradle Suspension.

tangular frame of iron bars is hung by the centers of its shorter sides at each end of the truck. The connecting bolt at the same time compressing a spiral spring. On

Fig. 457. Cradle Suspension.

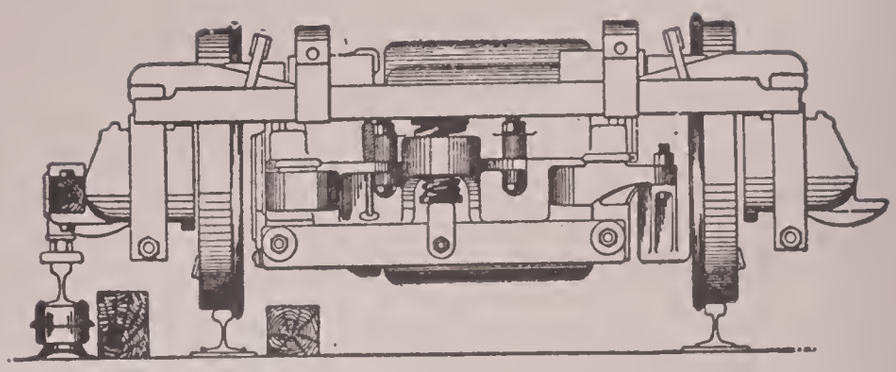


Fig. 458. Gibbs' Cradle Suspension, End View.

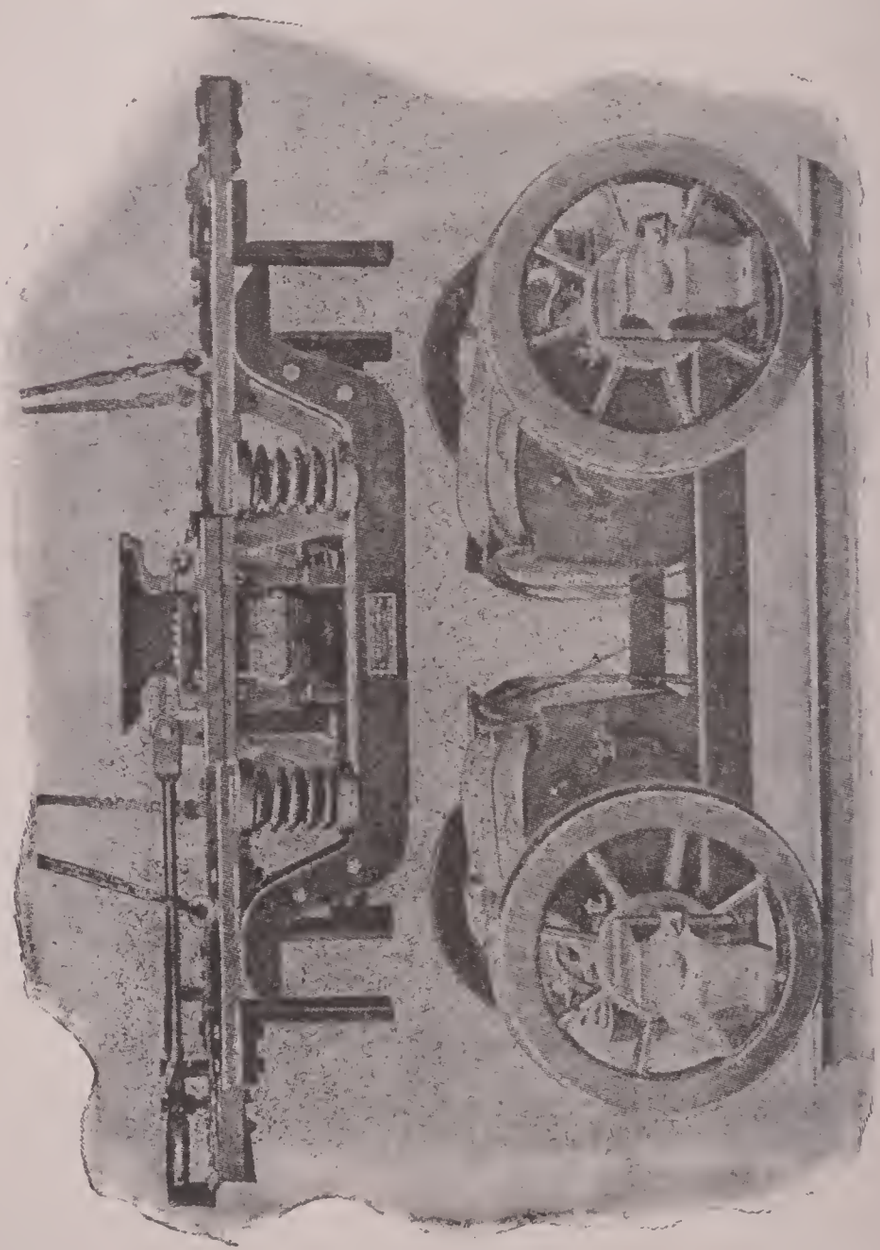


Fig. 459. Gibbs' Cradle Suspension with Truck Frame Lifted.

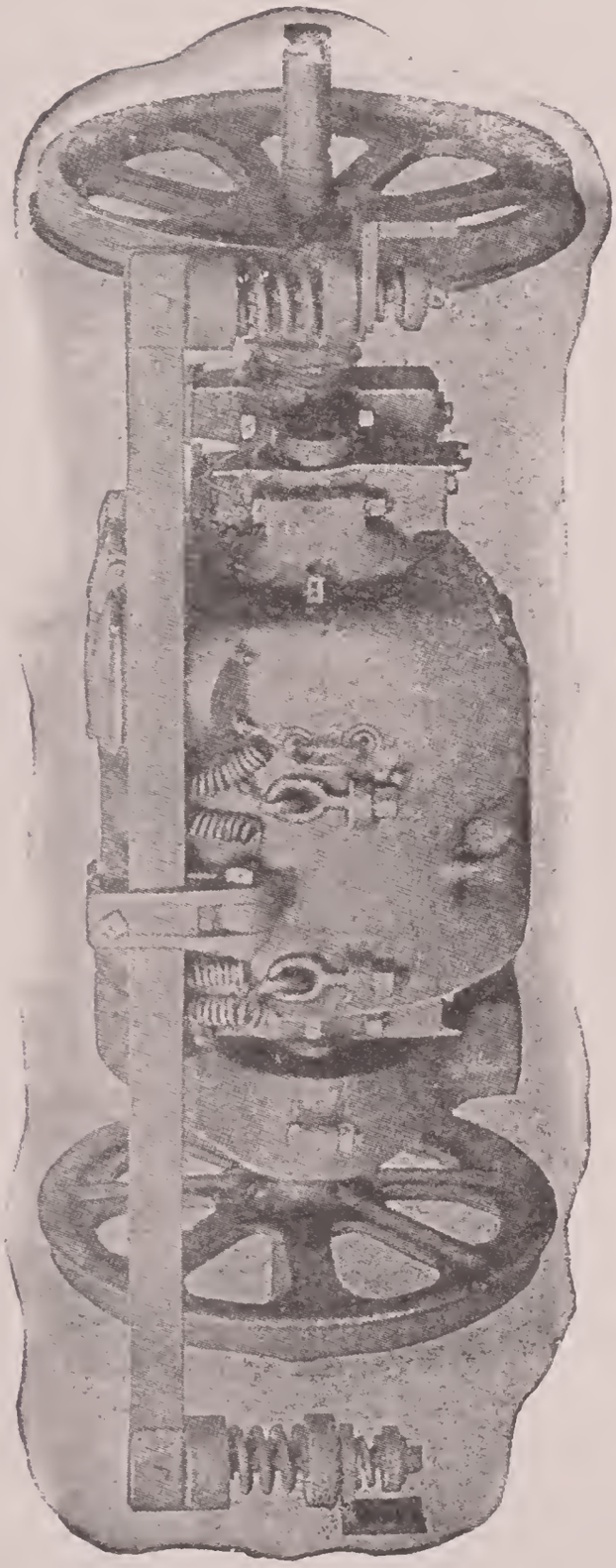


Fig. 460. Nose Suspension.

each side of the motor is a lug which is bolted to the long or side bars of this frame.

This suspension is the *cradle* suspension. It has many modifications. In Fig. 457 the center of end bar of cradle is slung without springs from a cross bar which is spring borne at the outside of the frame.

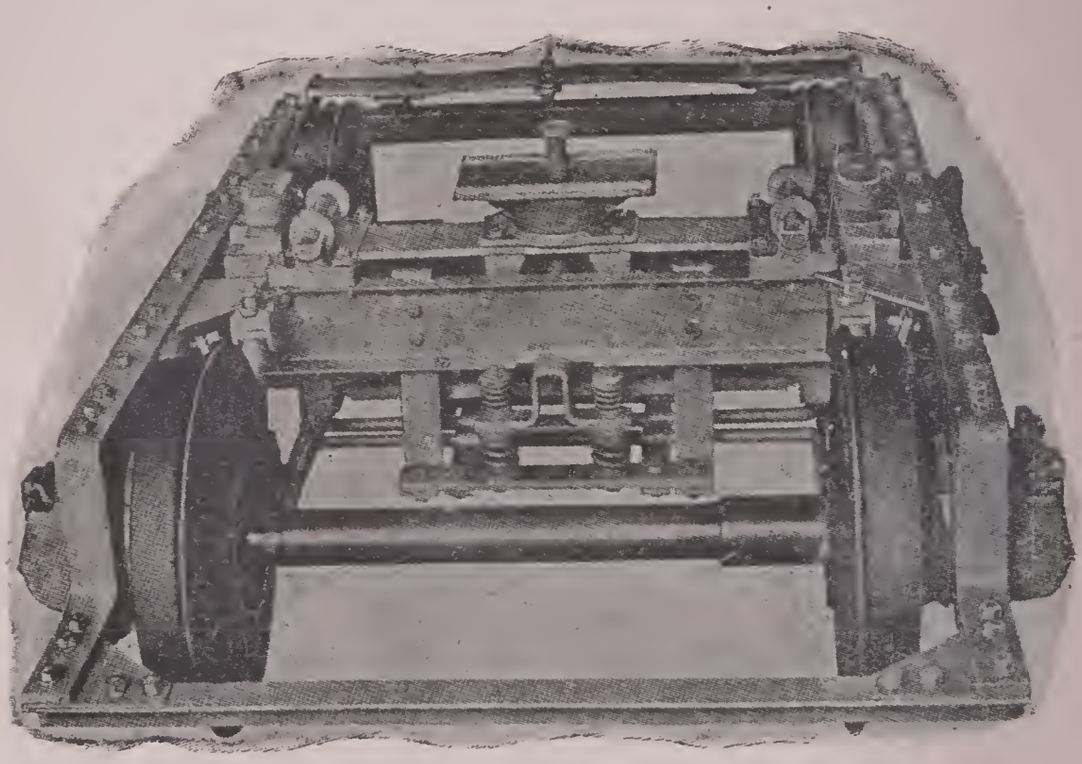


Fig. 461. Nose Suspension.

One of the best cradle suspensions is the Gibbs (Fig. 458) as shown in Fig. 459 the whole truck frame of a M C B truck may be hoisted clear of the wheels and motors.

The nose suspension is simpler than the cradle. The end of motor not resting on car axle is hung from a spring borne cross bar. See Fig. 460.

Another very simple nose suspension is shown in Fig. 461 where the truck transom has a frame bolted to it con-

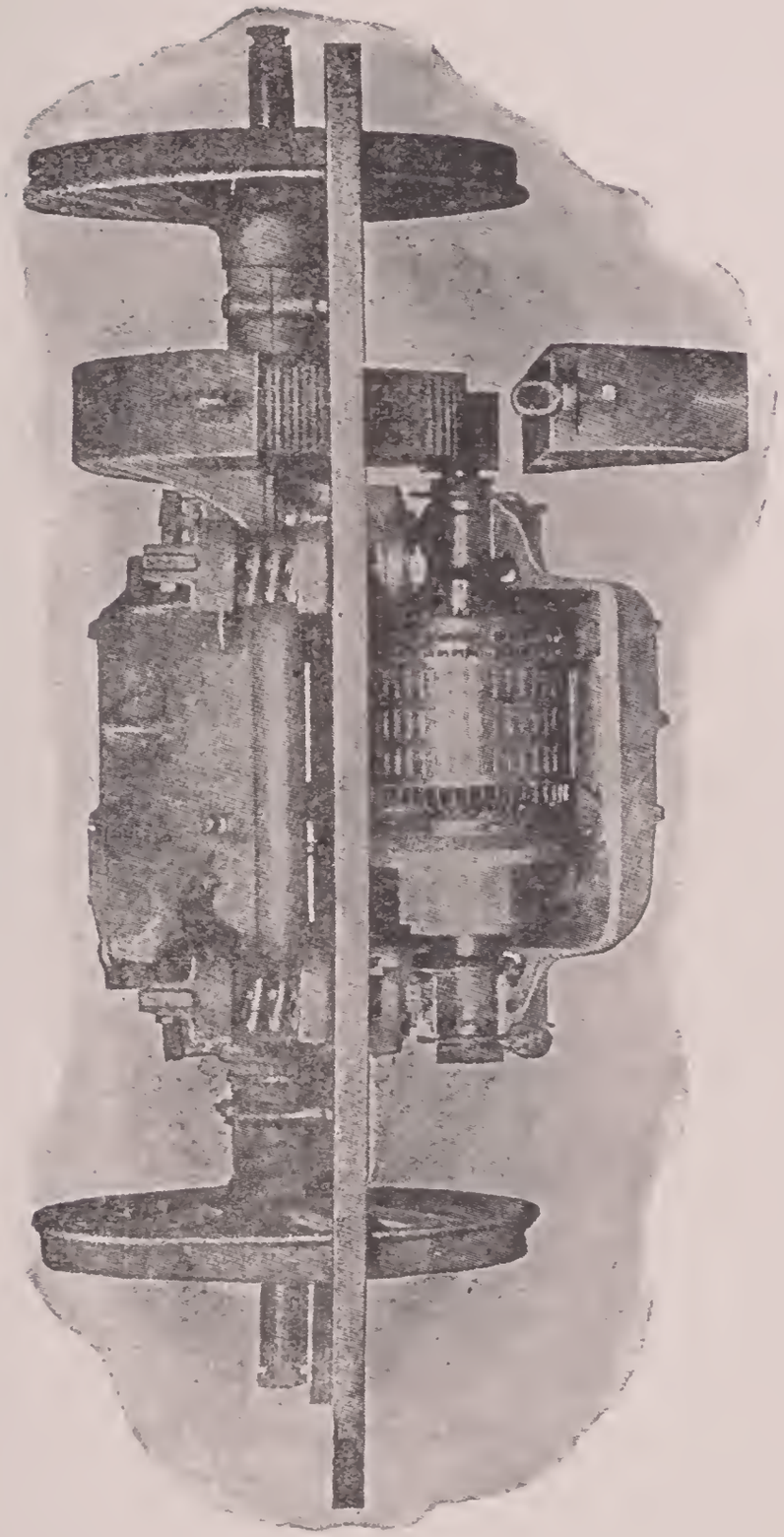


Fig. 462. Parallel Bar Suspension.

taining a spring supported U or loop. A lug or nose on the motor sticks into this U. This illustration shows the king pin, bearing plate, and side bearings all mounted on transom.

Fig. 462 shows a suspension made of two bars running length-wise of truck which hold the motors. These bars are each spring borne at ends of truck, directly from frame. In the illustration two long bars are supporting the parallel bars because there is no truck there to do it. Such a suspension needs four spring supports and is no more flexible than the cradle suspension using only two. It is called the *parallel bar suspension.*

LESSON 44.

Car Equipment.

The electrical equipment of a car consists of the motor truck, the controller, resistances, iron pipe conduits containing the motor circuits, and the motor control circuits,

Fig. 463. Lightning Arresters.

a trolley or set of third rail shoes and a few auxiliary pieces of apparatus. Some arresters are shown in Fig. 463. An arrester installed with a kicking coil is shown

in Fig. 464. A switch called a canopy switch is shown in Fig. 465. It is mostly used in interurban cars where the motorman's cab is built on front platform and this switch is installed over his head: It is a snap break switch and is used to cut off current from car at base of trolley.

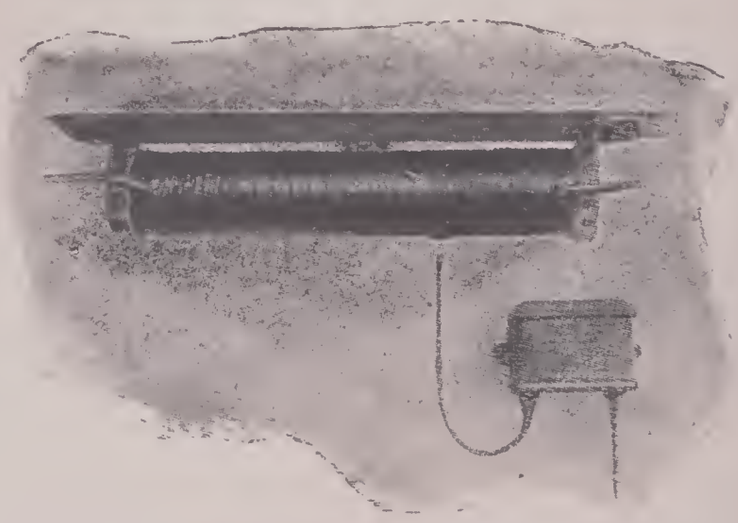


Fig. 464. Choke Coil and Lightning Arrester.

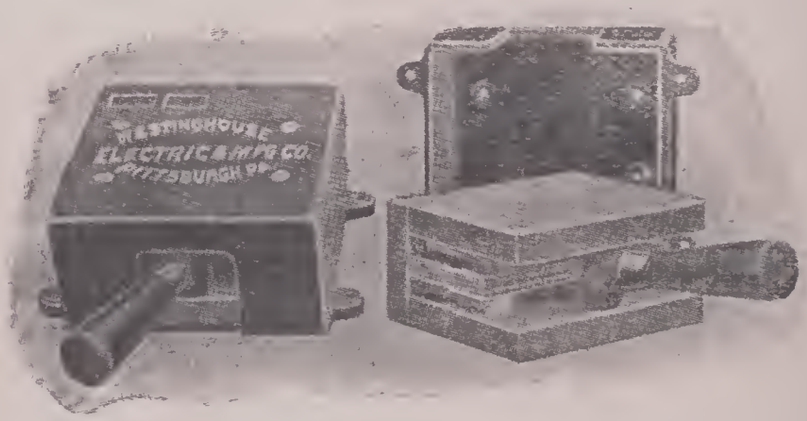


Fig. 465. Canopy Switch to Cut Off Current at Base of Trolley.

When a canopy switch has a magnet trip operated by current to motors it is called a current breaker. The one in Fig. 466 has a magnetic blow-out, which expels the arc through the chute shown on right side. The button on

front is to trip the breaker. The handle on top is for closing it.

Main fuses (Fig. 467) should be protected by iron cases but wood boxes are still used.

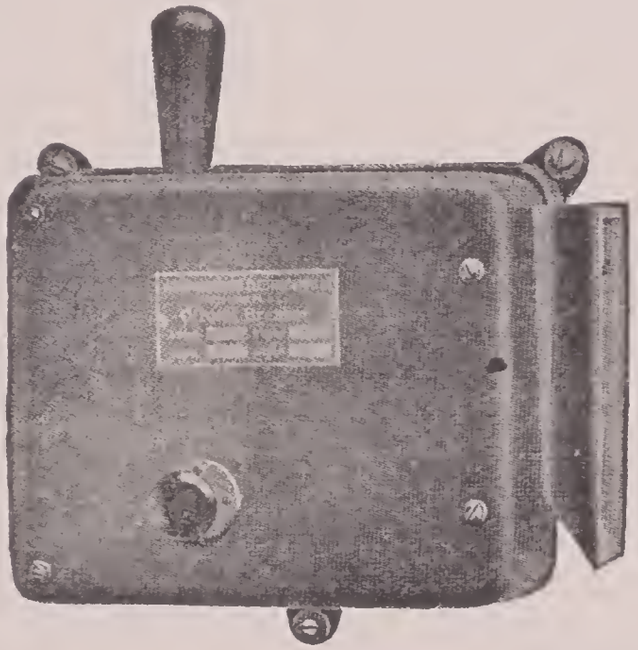


Fig. 466. Automatic Circuit Breaker.

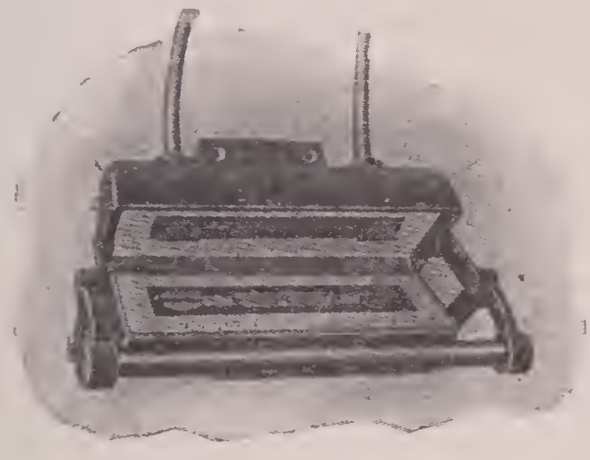


Fig. 467. Fuse Block.

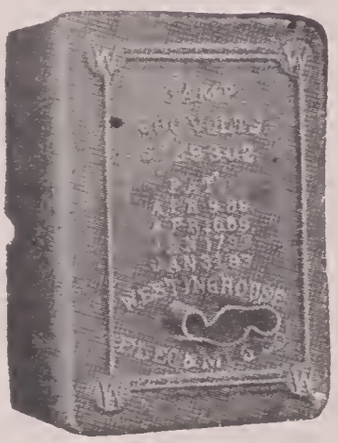


Fig. 468. Snap Switch for Lighting Circuits.

The car and vestibule lights are controlled by snap switches on porcelain bases, enclosed by porcelain or iron covers (Fig. 468). Head lights have same style switches of heavier construction.

Contact Devices.

The type of trolley with a wheel to collect current from wire is not satisfactory for high speeds. The wheel is apt

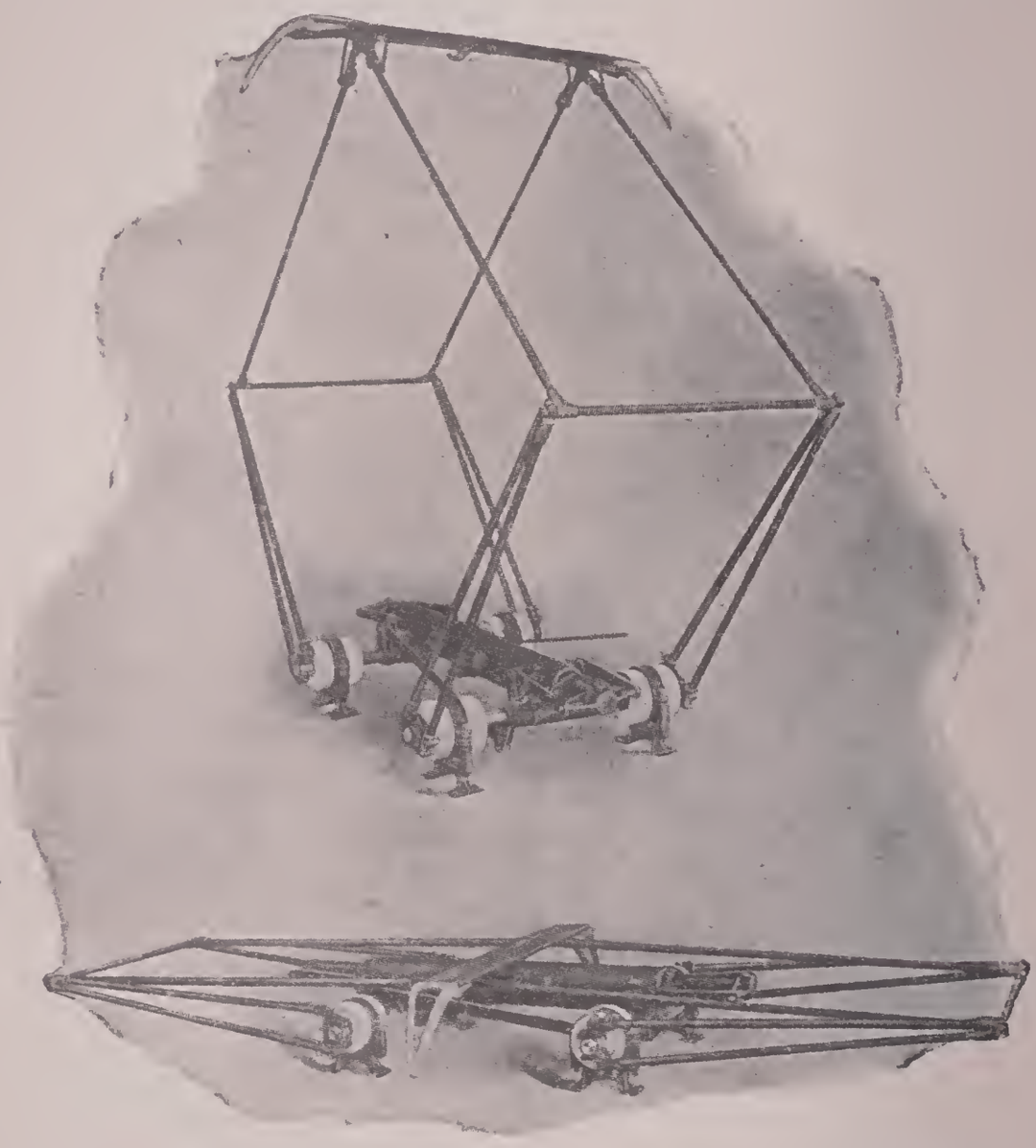


Fig. 469. Pantagraph Bow Trolley. Raised and Lowered.

to jump the trolley wire and smash the guy wires of ordinary, or the braces of catenary construction.

A bow trolley where the wheel is replaced by a broad plate of copper or iron some two or three feet wide and

three inches across, must be used for high speeds. Then no matter how the train sways the trolley and wire always keep in contact.

The latest form of bow trolley is called The Pantagraph Trolley, as shown in Fig. 469. It is raised and lowered by an air cylinder shown in center.

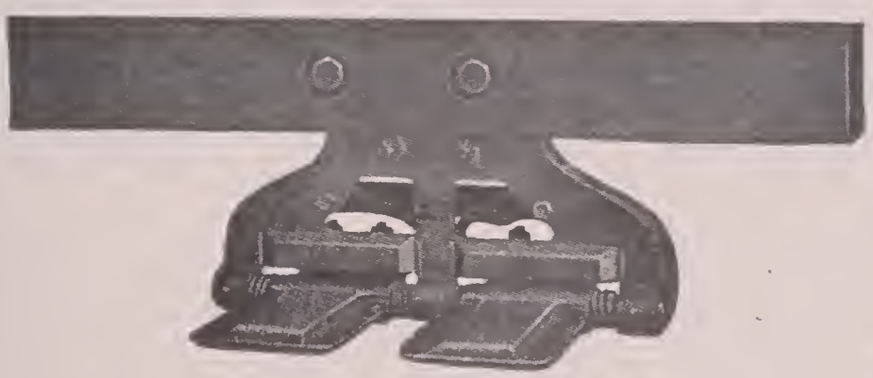


Fig. 470. Third Rail Shoes.

When a third rail is used shoes as in Fig. 470 are the current collectors. These are of cast iron pressed by springs against the top or bottom of the third rail.

Heaters.

In trains of motor cars the only way to heat cars is by resistances made hot by electric current. This is the most expensive way to heat and in interurban cars where motorman is always on front platform (the cars passing around a loop at each end of route) it is better to install a hot air or hot water heater and let motorman attend to it. This can be done at terminals and at turnouts or even at stops where eight or ten passengers are being let off or taken on.

When electric locomotives are drawing the standard railway coach, steam must be furnished. To do this steam heating plants with kerosene blue flame burners are placed in locomotives and attendance given by the second man in the cab.

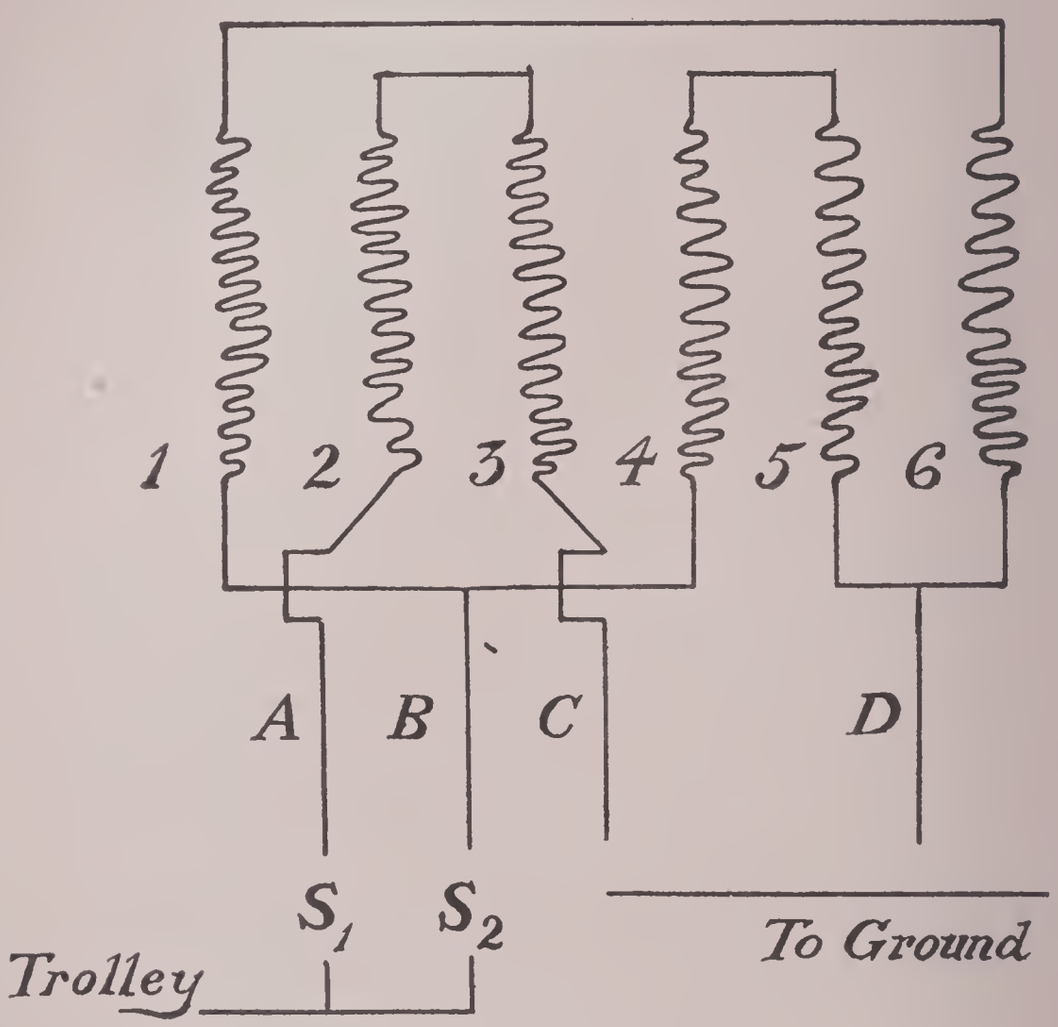


Fig. 471. Diagram of Car Heater Connections.

To furnish two degrees of temperature with electric heaters the heaters although all placed in series, are each individually connected as in Fig. 471.

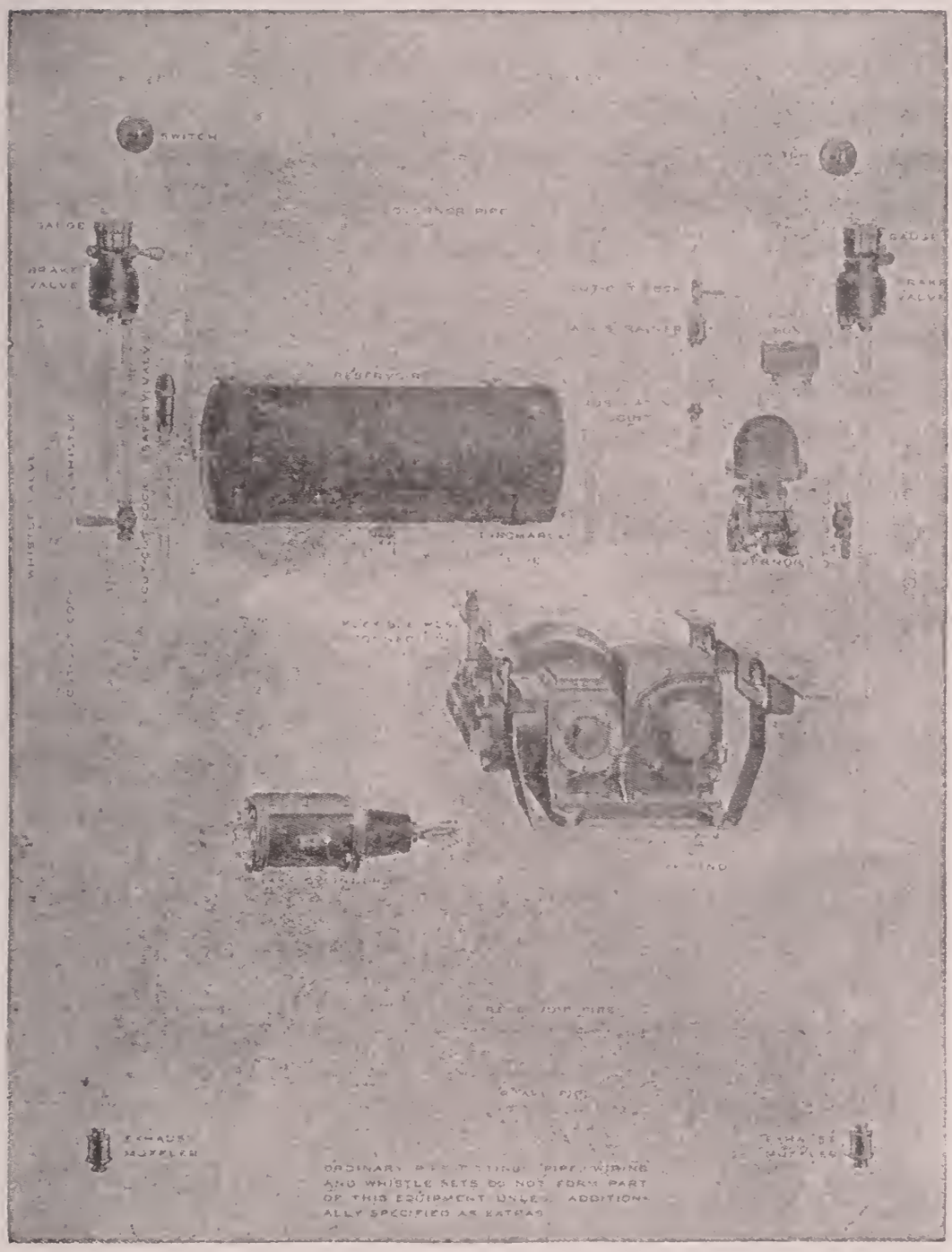


Fig. 472. Car Equipment Straight Air Brake.

Terminals A, B, are connected to the same lettered terminal of heater behind; C and D are connected to C and D of heater ahead.

The first heater has A and B connected to switches S_1 and S_2 which are connected to trolley. The last heater has C and D connected to a ground wire which is connected to some part of frame of truck.

If with switch S_1 closed a certain amount of heat is generated, with S_2 closed twice the heat is obtained, while with both closed the maximum heat is obtained, being three times that given by the switch S_1 alone.

Air Brake.

For complete description of all air brake equipment read Vol. III.

Suburban lines feeding steam roads usually run single cars which are fitted with a straight air equipment like Fig. 472.

The electric locomotives of the New York Central R. R. have the Westinghouse E-T equipment.

Practically all the motor car of railway coach type running in trains have the regular automatic air brake with an air compressor on each motor car.

The parts of such a compressor are shown in Fig. 473, the complete compressor in Fig. 474, and a side view of compressor in its suspension is given in Fig. 475.

The New York Central motor cars have a governor of type shown in Fig. 472.

The New York Central locomotives and the Pennsylvania motor cars have a governor as in Figs. 476 and 477. Showing it closed and open.

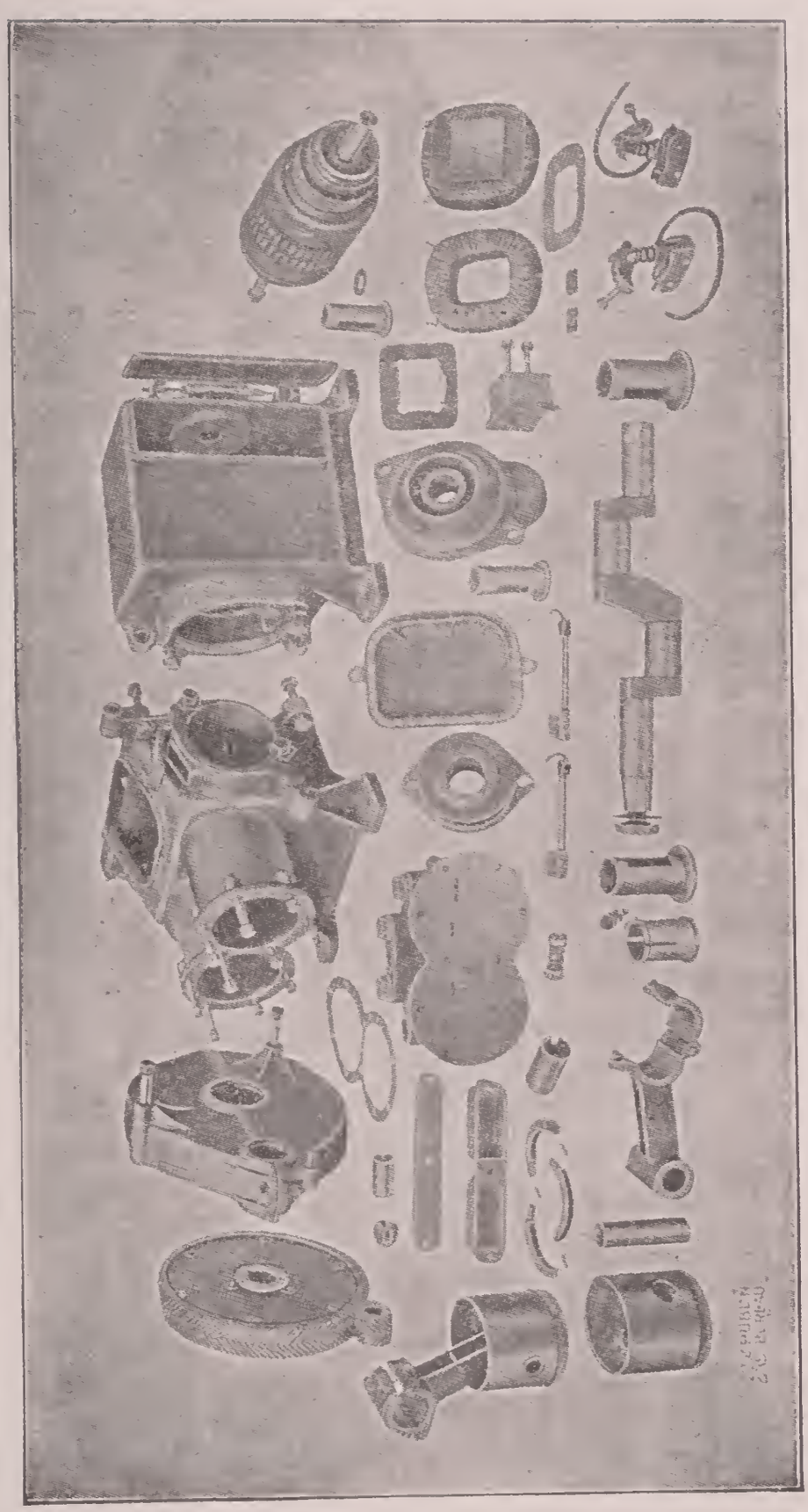


Fig. 473. Parts of Motor Driven (Geared) Air Compressor.

The construction is shown in Figs. 478 and 520. The cylinder head is provided with a tapped hole for the insulated pipe which makes connection between the governor and the compressor reservoir. The head is so con-

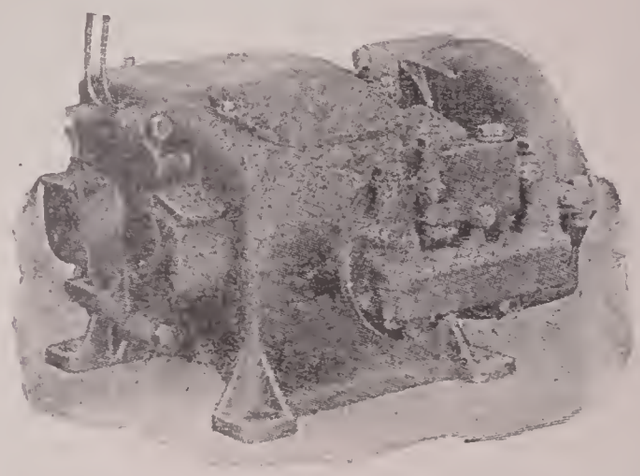


Fig. 474. Motor Driven (Geared) Air Compressor.

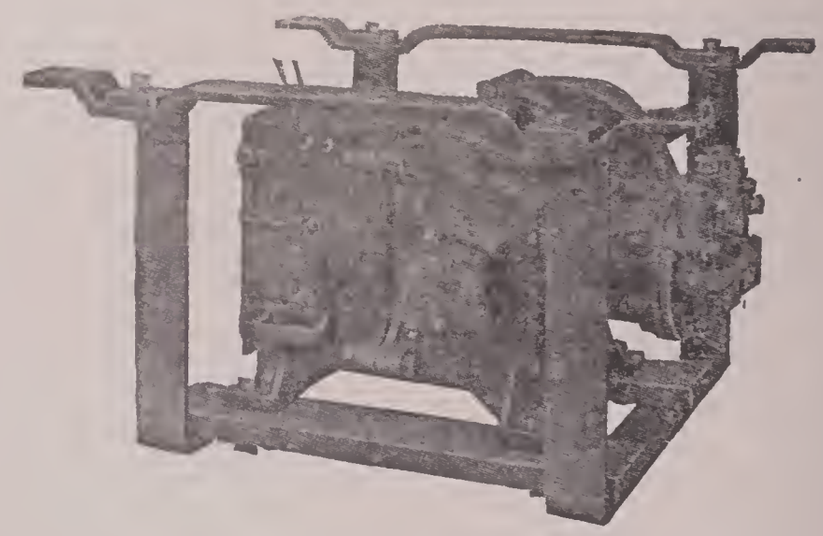


Fig. 475. Air Compressor (Fig. 474) in Suspension.

structed that this connection may be placed at the back or at either side of the governor, as desired. It is bolted to the frame and holds the rubber diaphragm A against the retaining ring. This ring serves as an abutment for

the piston B against the upper surface of which the diaphragm A is pressed. The lower side of the piston is acted upon by the operating spring C, the pressure of which is adjusted by means of the screws R bearing against the washer S. Attached rigidly to the piston B is the rod D, the lower end of which is connected to one of the operating levers. The largest of these levers is

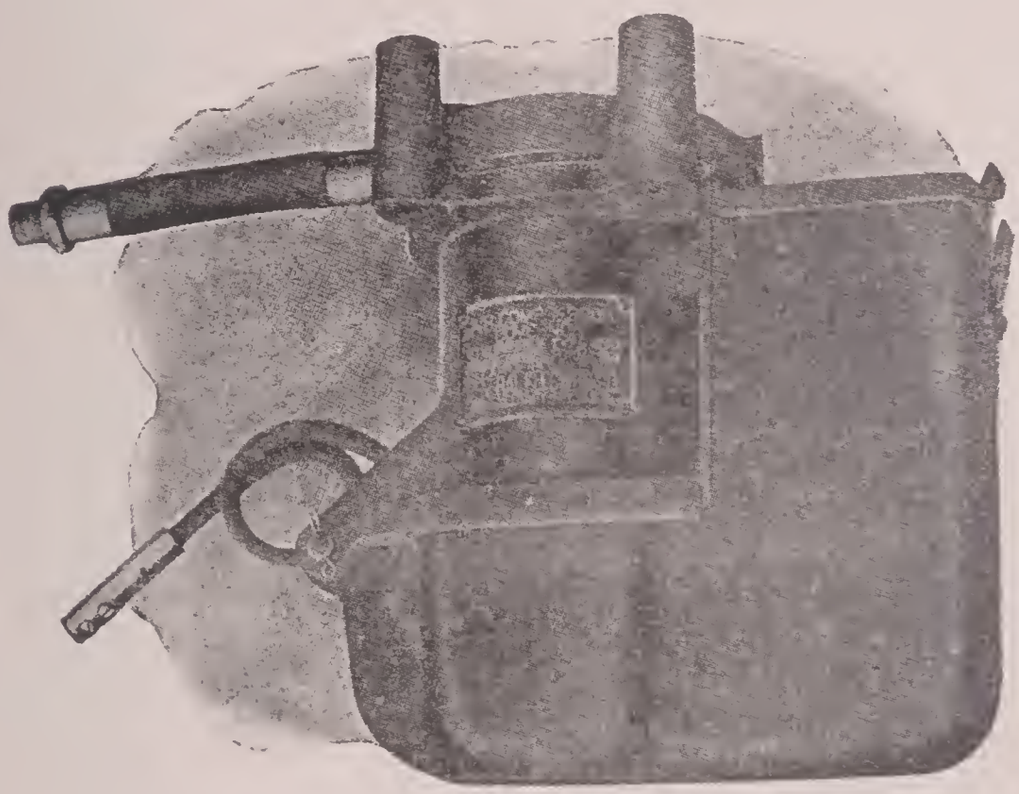


Fig. 476. Air Compressor Governor, Case Closed.

provided with a recess into which a mica insulated stud has been forced by hydraulic pressure. Attached to the stud are the cable terminal and the spring carrying the contact finger. The finger tip through which the circuit is completed and broken is so made as to be readily renewable when worn. This finger completes the circuit

through the stationary contact, the tip of which is also renewable. Enclosing these contact members is the arc chute, which is composed of a special molded insulating compound and is provided with renewable plates of a highly refractory material. This material has the prop-

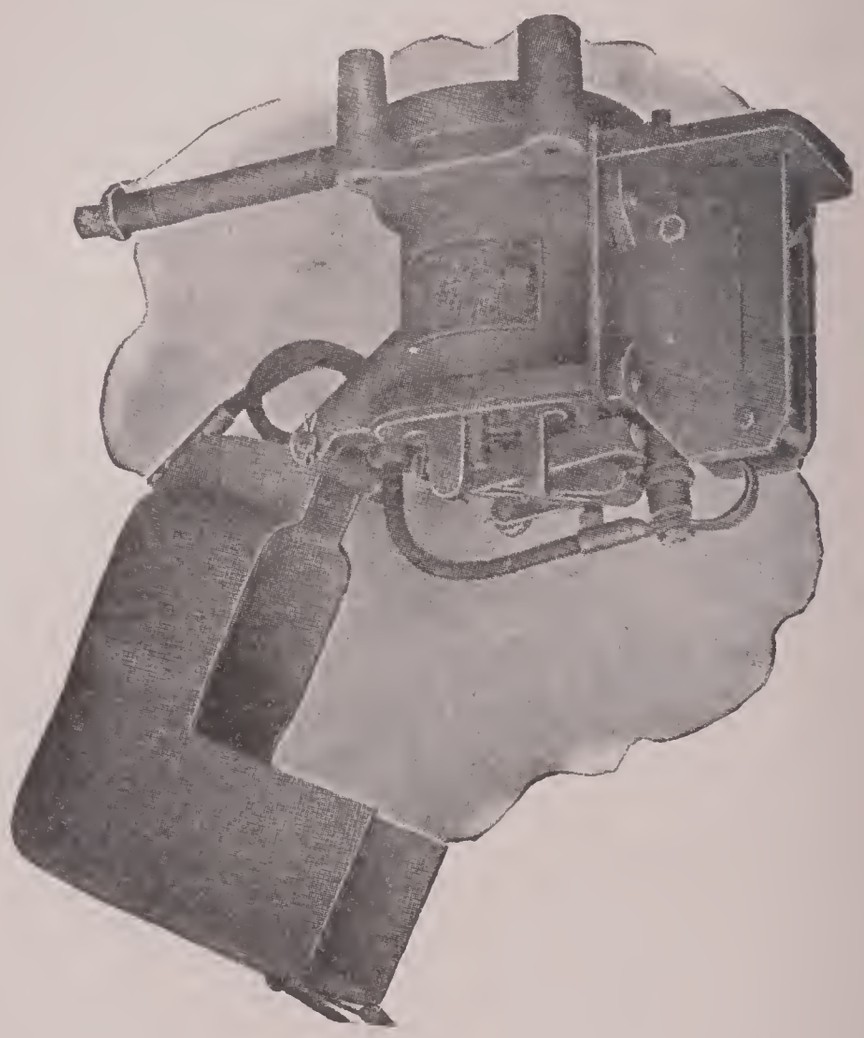


Fig. 477. Air Compressor Governor, Case Opened.

erty of resisting the action of the electric arc to a great degree. In series with this circuit is the blow-out coil O, for producing the magnetic field which extinguishes the arc when the circuit is broken. This coil is made of

enameled copper ribbon wound edgewise, and connected with it is the line terminal, which is provided with two set screws for clamping the wire. The protecting cover is hinged at the back of the frame and is held in the

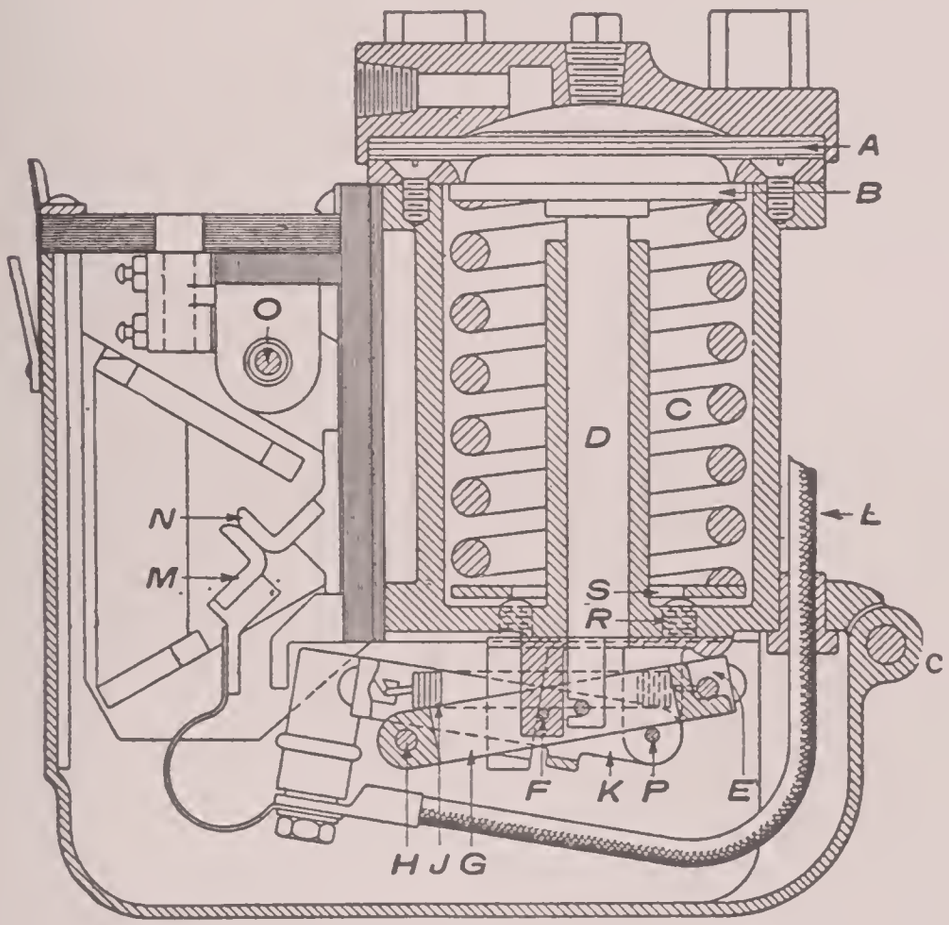


Fig. 478. Construction of Air Compressor Governor.

closed position by a spring catch. On the inside of this cover adjacent to the arc chute is a plate of insulating material which prevents the possibility of the arc striking the metal.

Operation.

The action of this governor in opening and closing the motor circuit of the compressor is as follows:

As the compressor continues to operate, thereby increasing the pressure of air in the reservoir, the pressure in the chamber above the diaphragm A rises and forces the piston rod downward against the action of the operating spring C, turning the lever E around its fulcrum F. This brings the pivot H above the centre line of the tension springs J, which connect the intermediate lever G with contact carrying lever K. The action of these springs then pulls the end of the intermediate lever downward; this movement quickly carries the centre line of the springs past the pivot P, thus reversing the action of these springs on the contact carrying K, and causing the free end of this lever to be drawn downward, separating the contacts M and N with a quick snap.

The object of this double system of levers is to maintain a constant pressure between the contacts until the tripping point is reached, thus preventing burning of the contacts.

As the pressure in the reservoir is reduced the piston rod O raises the rear end of the lever E, a projection of which engages with the intermediate lever G. This carries the center line of the tension springs J above the pivot of the contact carrying lever K and thereby pulls the contact finger upward, quickly closing the circuit.

The information given here is the same as that which the Pennsylvania R. R. demands that the motor-men should know before operating its trains.

The following pages contain a description of the electrical apparatus used on the motor cars of the West Jersey and Seashore R. R., one of the Pennsylvania lines running from Philadelphia to Atlantic City. This road is practically a straight line between the two cities with no grades worth mentioning. It is 60 miles long and can be done by express trains in very little over an hour.

These conditions while ideal for steam locomotives are even yet more suitable for electric traction. When it comes to local trains the electric cars are vastly superior and can make much better time with increased economy.

INSTRUCTIONS FOR THE OPERATION OF MULTIPLE UNIT CONTROL.

GENERAL DESCRIPTION OF APPARATUS.

1. THE MOTOR CARS ON THE WEST JERSEY AND SEASHORE RAILROAD are equipped with two General Electric (No. 69-C) 200 horse power railway motors, both of which are mounted on one truck, known as the MOTOR TRUCK. The Sprague-General Electric (type M) multiple unit system of control is used.

2. BY MULTIPLE UNIT CONTROL is meant the operation of a train of two or more motor cars from a single master controller on any car in the train; that is, a train of several cars, each propelled independently by its own motors, is controlled as one car.

3. THERE ARE TWO CONTROL CIRCUITS on each car: First, the MASTER CONTROL, which is operated by the motorman; second, the MOTOR CONTROL, which depends for its operation on the master control. Both master control and motor control cables are enclosed in iron pipe conduit.

4. EACH MOTOR CAR is provided with two master controllers, one at each end of the car in the motorman's compartment. All master controllers are connected to a seven-wire TRAIN CABLE running the entire length of each car and connected together between cars by the TRAIN CABLE JUMPER. Current received through the master controller and train cable

operates electrically controlled switches known as CONTACTORS on each car, and establishes the motor control on their respective cars. The motor control is local with each car and can be governed by any master controller on the train.

5. EACH MOTOR CAR TAKES CURRENT from the third rail, through the third rail shoes, or from the trolley wire, through the trolley. All third rail shoes and trolleys are connected through switches to a BUS LINE, which runs the entire length of each car and is connected together between the cars by the BUS LINE JUMPER; therefore, if any third rail shoe or trolley is in contact with the third rail or trolley wire, all motors of the train can be supplied with current through the bus line.

MOTOR CONTROL.

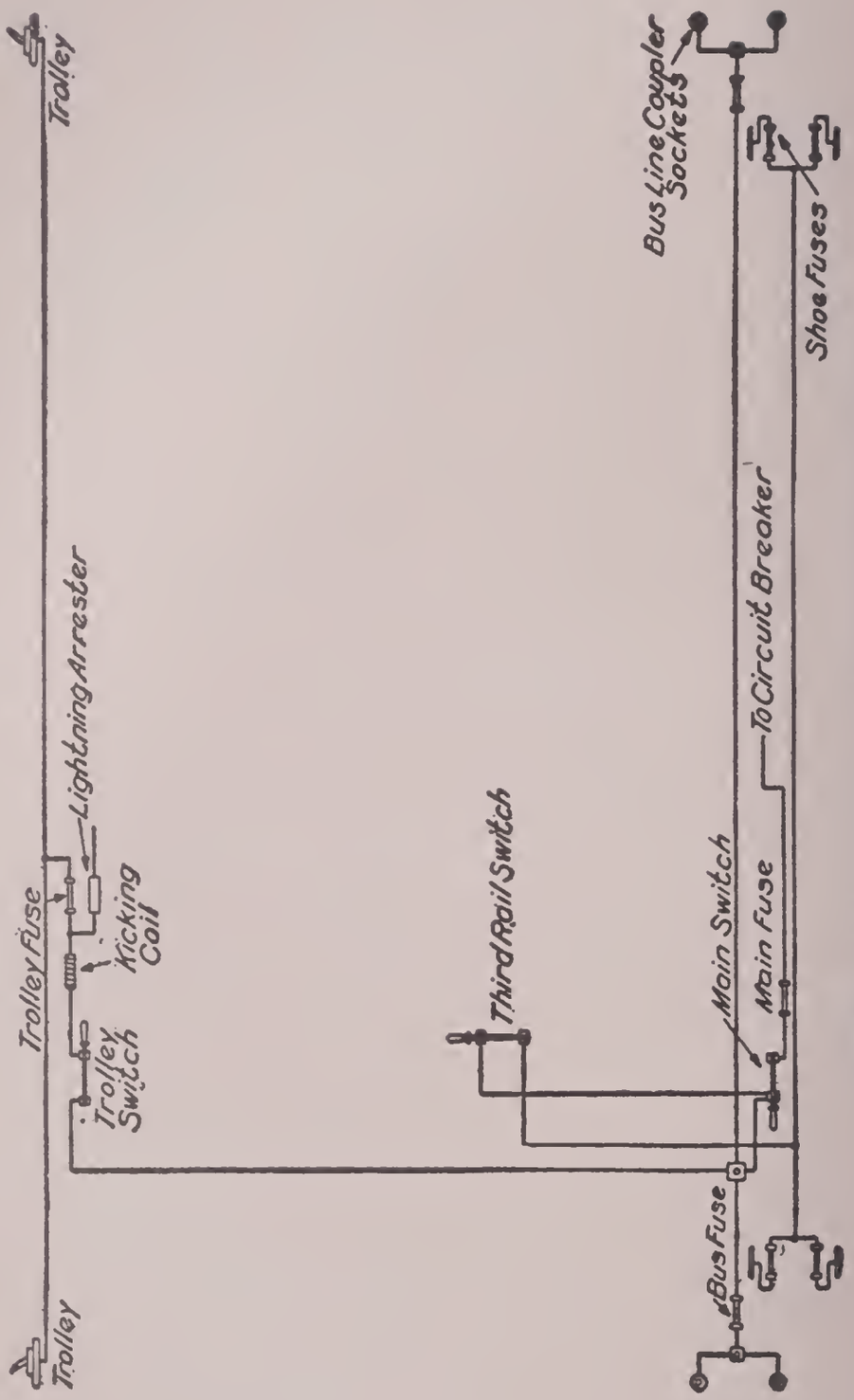
6. THE MOTOR CONTROL CIRCUIT (Fig. 479) is the circuit forming the path of the current from the third rail shoes or trolley through the motor control apparatus and motors to the track rails, and is THE MAIN CIRCUIT.

7. THE ESSENTIAL PARTS of the motor control of each car comprise the following apparatus:

One set of fifteen CONTACTORS, which close and open the circuit to the motors.

One REVERSER, which determines the direction of train movement.

One set of eight RESISTANCES, which limit the flow of current to the motors when starting.



General Arrangement of Motor Control Wiring.

Fig. 479.

ONE CIRCUIT BREAKER, which protects the motors and motor control apparatus against excessive current.

ONE MAIN FUSE, which—like the circuit breaker, and in addition to it—protects the motors and motor control apparatus against overload in case circuit breaker fails to operate.

ONE MAIN SWITCH, by which the current can be cut off from motor control circuit for inspection or in case of defective apparatus.

ONE THIRD RAIL SWITCH, by which current can be cut off from third rail shoes when operating from trolley.

ONE TROLLEY SWITCH, by which the trolley can be cut off from the bus line.

FOUR THIRD RAIL SHOES, which collect current from the third rail.

FOUR SHOE FUSES, which protect the apparatus and car wiring against excessive current.

TWO TROLLEYS, either of which take current from the trolley wire.

One TROLLEY FUSE, which protects the apparatus and car wiring from excessive current.

One BUS LINE, which, together with the bus line jumper, connects all shoes and trolleys of a train together.

TWO BUS LINE FUSES, which protect the bus line against excessive current.

ONE KICKING COIL and one LIGHTNING ARRESTER, which protect the circuits and apparatus against lightning discharges.

8. THE FOUR THIRD RAIL SHOES are connected together through the shoe fuses by a cable, from which a connection is made through the third rail switch on switchboard, through the main switch, main fuse, circuit breaker, contactors, resistances, reverser and motors to the track rails.

9. THE TWO TROLLEYS are connected together by a cable, from which a connection is made through the trolley fuse, then through the kicking coil and trolley switch, located in a box on the roof of the car, to the bus line, from which a connection is made between switch. From the main switch the circuit is the same as from the third rail shoes. A connection is made between the trolley fuse and kicking coil through a lightning arrester, located in the box with the kicking coil on the roof of the car, to ground.

10. THE CONTACTORS, fifteen in number, are enclosed in an iron box, known as the contactor box, located under the car.

The Contactor (Fig. 480) is a switch, the movable portion of which is operated by an electro-magnet receiving line current through the master controller and the train cable. The main contact is made between two heavy copper tips, which are enclosed in an arc chute. A magnetic blowout is provided, having poles extended along two sides of the arc chute, for extinguishing the arc formed in breaking the circuit.

By means of the contactors the motor control is established on individual cars.

11. THE CONTACTOR BOX (Fig. 481) is located beneath the car, about midway between the trucks.

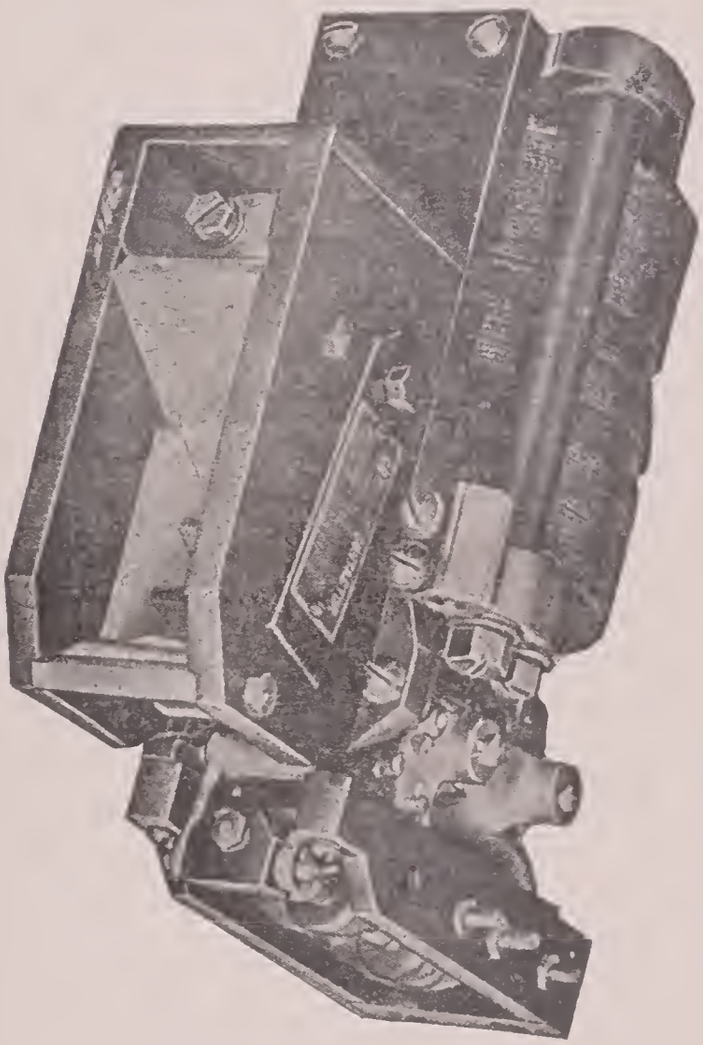


Fig. 480. Contactor.

This box is of iron, lined with asbestos and other insulating materials to prevent short circuits, and is provided with two hinged sheet iron covers. When it is desired to inspect the contactors the sheet iron covers

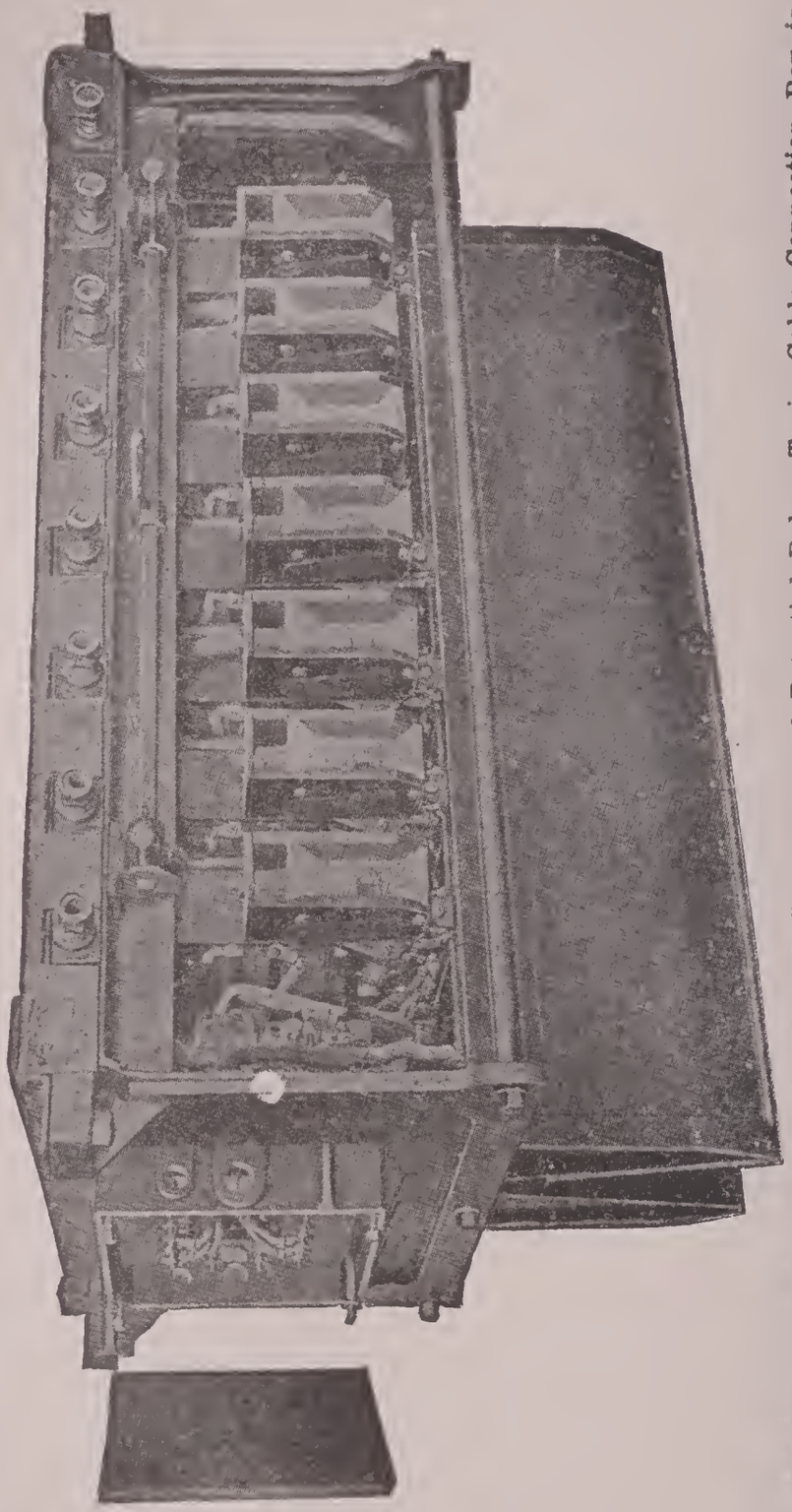


Fig. 481. Contactor Box. Contain 15 Contactors and Potential Relay. Train Cable Connection Box is Mounted on Left End.

can be dropped by releasing the catches which hold them in place.

12. THE REVERSER (Fig. 482) is enclosed in a metal box, and located near the end of the contactor box toward the trailer truck.

The movable part of the reverser is a rocker arm, controlled by two electro-magnets, one for each direction. These magnets are operated by current from the master controller through the main cable, the connections being made so that only one magnet can receive current at a time. Cables from the motor armatures and fields are connected to the fingers of the reverser, and by means of contact pieces mounted on, but insulated from, the rocker arm, proper connections of armatures and fields are established for producing forward and backward movement of the car.

The control connections for the reverser are so arranged that, unless the reverser is at the proper position, current is cut off from the contactors, and consequently the motors on that car receive no current. When the reverser is in the correct position it is electrically locked and cannot be operated while the motors are taking current.

The reverser is always closed, either in the forward or backward position, depending on whether the master controller handle has been moved to the left or to the right.

13. THE RESISTANCE (Fig. 483) is located beneath the car, near the contactors, and is made up of cast iron grids mounted in, and insulated from, an iron frame.

These resistances are used to regulate the flow of current to the motors while the car is accelerating. Cables

Fig. 482. Reverser.

connect the various resistances to different contactors, so that sections of the resistance may be cut out to increase the speed. Resistances are used only in starting, switching, or moving at low speeds, and are entirely cut out either in the one-half or full speed positions of the master controller handle.

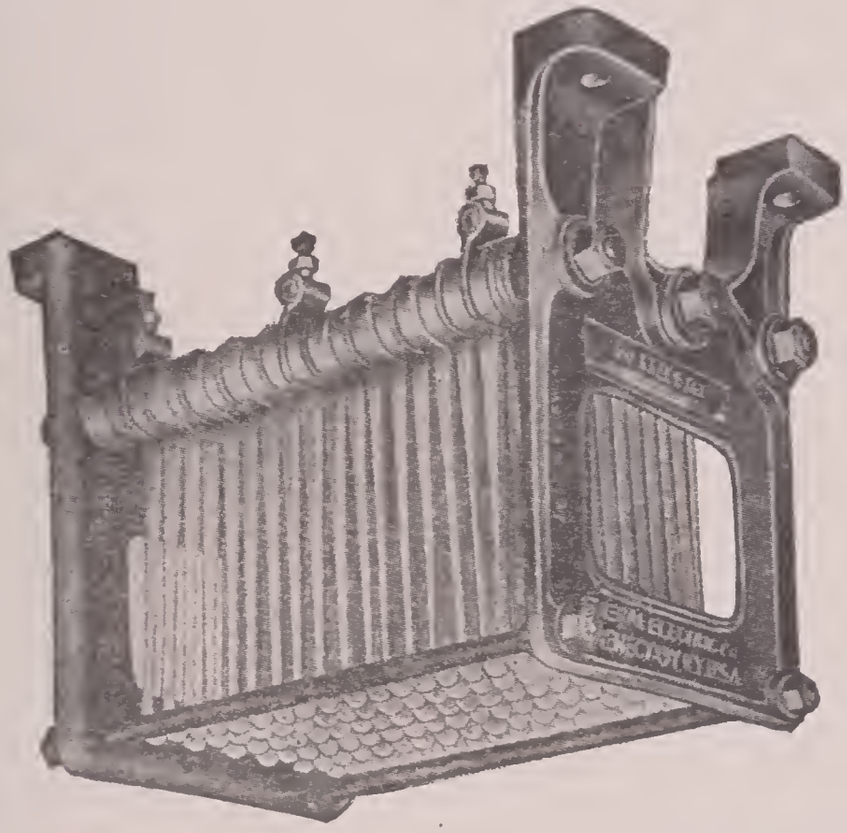


Fig. 483. Motor Control Rheostat.

14. THE CIRCUIT BREAKER (Fig. 484) is enclosed in an iron box, located beneath the car at the end of the contactor box toward the trailer truck.

The circuit breaker is similar in construction to the contactor, but designed to carry and break the full current taken by the car. It is closed and opened by means

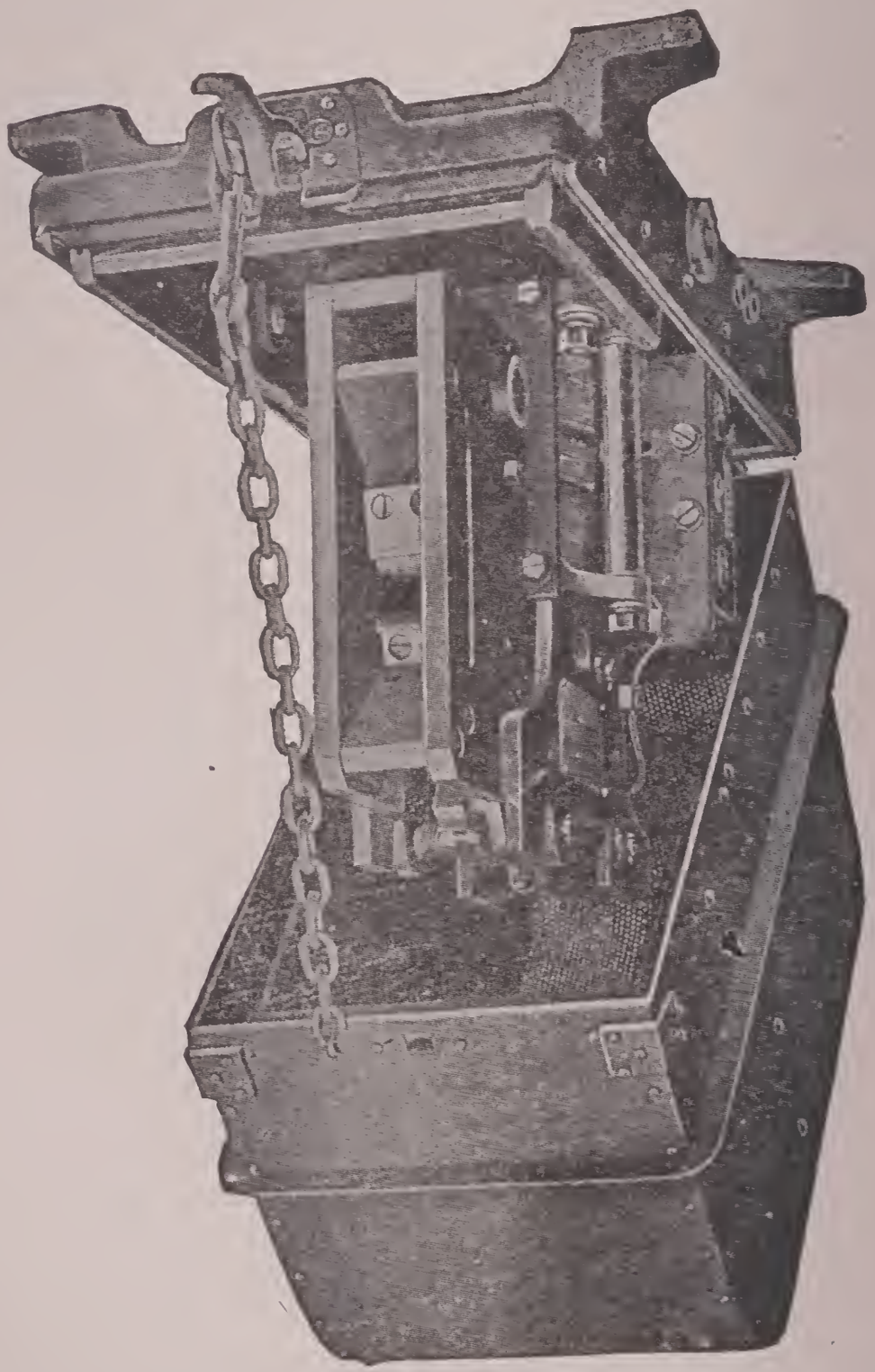


Fig. 484. Circuit Breaker.

of two electro-magnets, acting independently, and operated by current through the train cable and the circuit breaker switch (Fig. 485) which is located in the motorman's cab, above the master controller. The circuit breaker on any car is opened automatically when exces-

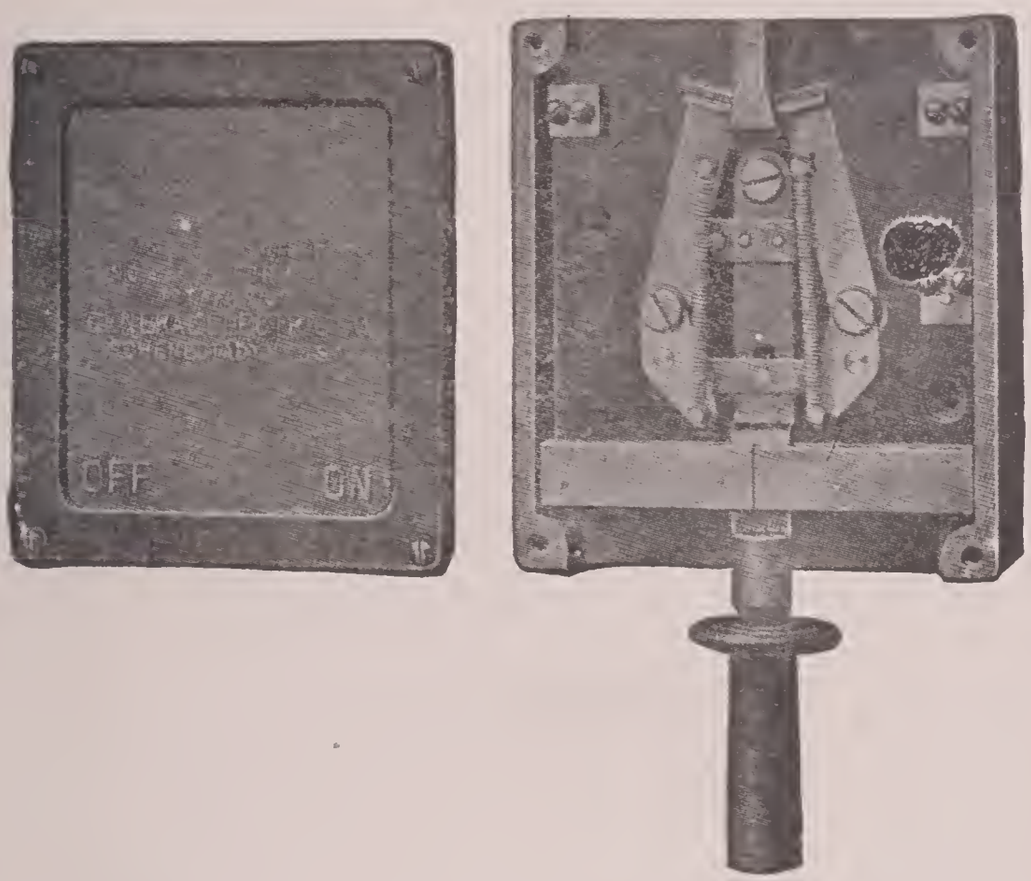


Fig. 485. Circuit Breaker Setting and Tripping Switch.

sive current flows through the motor circuits on that car. As the setting and tripping circuits of all circuit breakers of a train are connected through the train cable, all circuit breakers are closed and opened simultaneously by operating the circuit breaker switch.

The circuit breakers are normally closed when the train is ready for operation.

15. THE MAIN FUSE (Fig. 486) is located beneath the car, at the trailer end, near the main switch.

It is made from a thin copper ribbon and is contained in a box composed of insulating material. Sheet iron poles partially surround the insulation and provide a magnetic blowout for extinguishing the arc formed when the fuse blows.

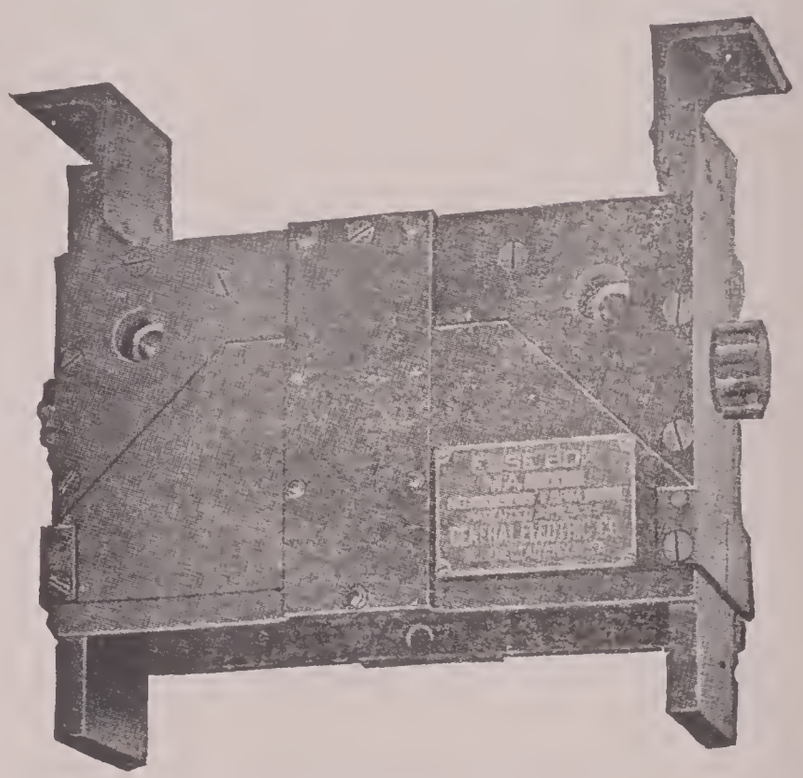


Fig. 486. Main Fuse.

The fuse is held in place by copper clamps, fastened with thumb screws having insulated handles. It may be replaced after opening the main switch, loosening the clamps and removing the ends of the old fuse. Ordinarily the current breaker will open automatically from excess current before the fuse has time to blow.

16. THE MAIN SWITCH (Fig. 487) is located in a box beneath the car. It is a quick-break, knife-blade switch, and is used to cut off the supply of current to

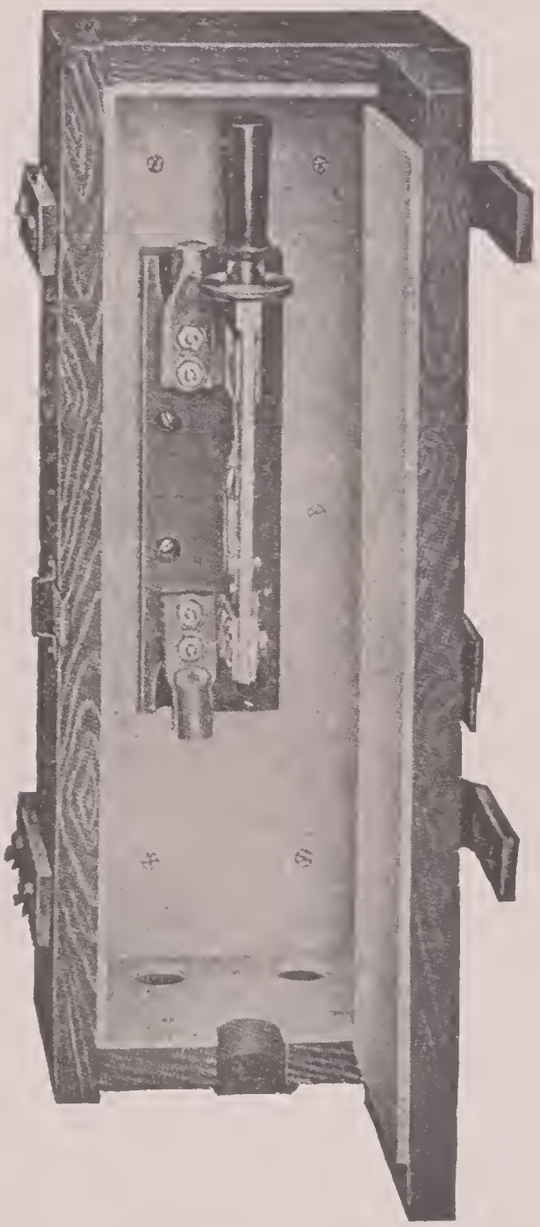


Fig. 487. Main Switch.

the motor circuit from both trolley wire and third rail. This switch is normally closed, BUT SHOULD ALWAYS BE OPEN when examining or working on the motor control apparatus.

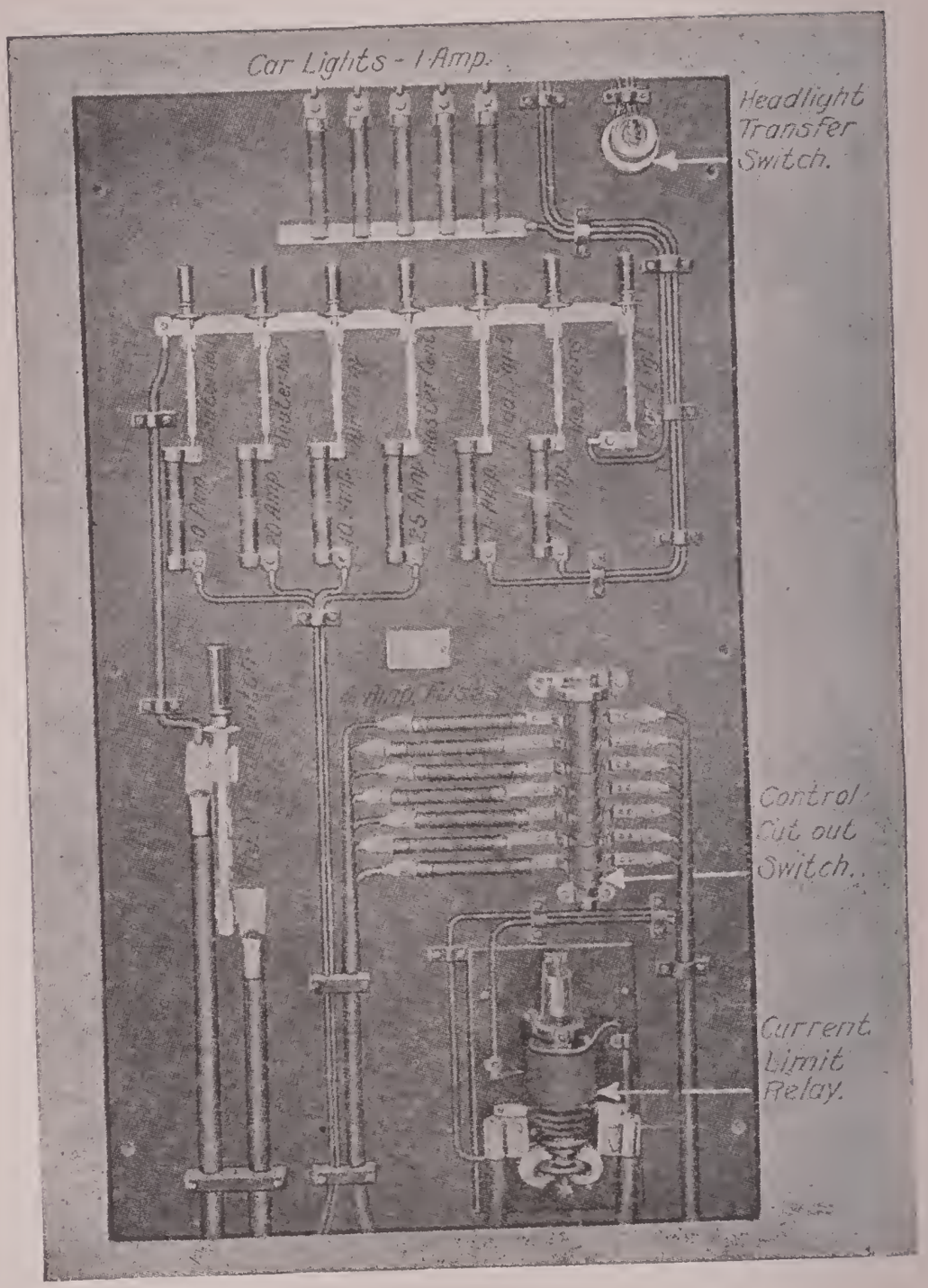


Fig. 489. Switchboard on West Jersey & Seashore Cars.

17. THE THIRD RAIL SWITCH is located on the switchboard (Fig. 489). It is a quick-break, knife-blade switch, and is used to cut off current from the third rail to the motor control circuit and to cut out the third rail shoes when operating from the trolley wire.

This switch is normally closed when the car is taking current from the third rail and open when taking current from the trolley wire. THE SWITCH SHOULD NOT BE OPENED WHILE THE MOTORS ARE TAKING CURRENT, EXCEPT IN AN EMERGENCY.

18. THE TROLLEY SWITCH is located in a box on the car roof. It is a quick-break, knife-blade switch, and is used to cut off the trolley and its fuse from the bus line circuit. This switch is normally closed, BUT SHOULD ALWAYS BE OPEN WHEN WORKING ON THE TROLLEY OR RENEWING A TROLLEY FUSE.

19. THE BUS LINE COUPLER SOCKETS, four in number, are located under the platforms, two at each end of the car.

The coupler socket (Fig. 490) is composed of a body of moulded insulating material, containing a large split plug contact. Supporting feet of malleable iron are secured to this insulating body for attaching to the under side of the car platform. The socket is provided with a hinged lid, having a projection on the inside to hold the jumper plug in place. The cover also excludes dirt and water when the jumper is not inserted. Only one of the two bus line coupler sockets at each platform is in use at a time.

20. THE BUS LINE JUMPER (Fig. 491) is used to connect the bus line coupler sockets on adjacent cars. It consists of a short section of flexible cable, with a plug attached to each end, and completes the bus line between the cars. Only one bus line jumper is required

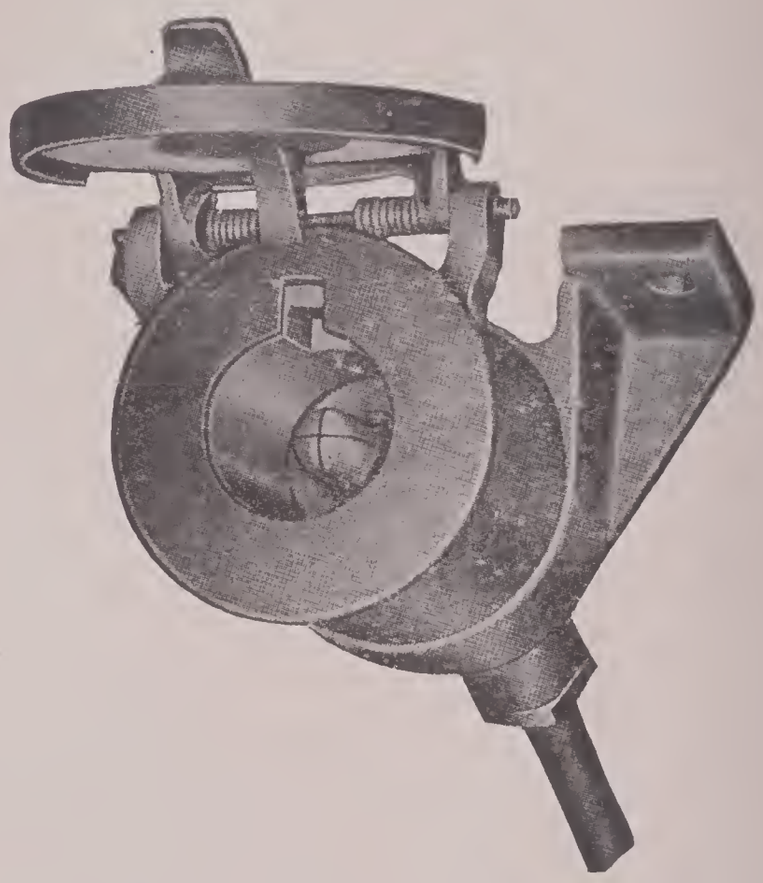


Fig. 490. Bus Line Coupler Socket.

for connecting between adjacent cars, the additional sockets being provided so that cars may be turned end for end or coupled in any desired relation.

21. THE BUS LINE FUSES, two in number, are located beneath the car, one at each end. They are similar to the main fuse. These fuses are placed in the bus line circuit to protect it against excessive currents.

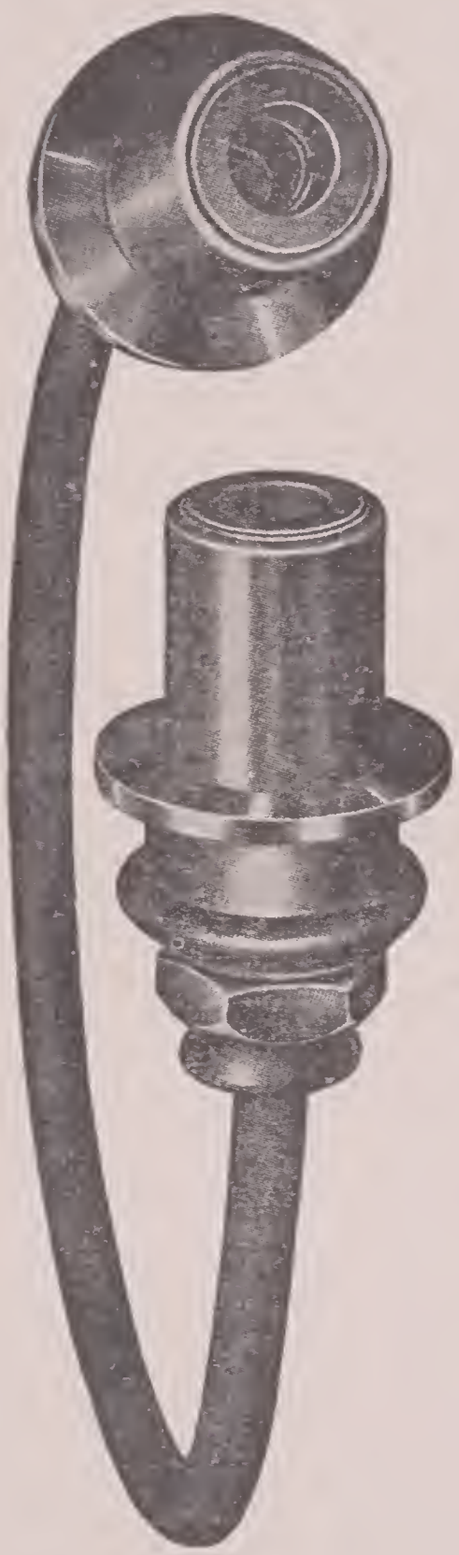


Fig. 491. Bus Line Jumper.

22. THE BUS LINE JUNCTION BOXES, two in number, are located beneath the car, one at each end.

The box is made of cast iron and contains an insulated board, to which is secured a single stud bolt for holding the cable terminals. This box is provided for connecting the bus line coupler sockets to the bus line cable.

23. THE BUS LINE CONNECTION BOX is located beneath the car, midway between the trucks.

This box is similar to the bus line junction box, and is provided for connecting the third rail and trolley circuits to the bus line cable.

24. THE SHOE FUSE BOXES, four in number, are located on the wooden shoe beams, one on each side of each truck. The box is similar to the main and bus line fuse boxes and contains the shoe fuse.

25. THE TROLLEY FUSE BOX is located on the roof of the car. It is similar to the main and bus line fuse boxes and contains the trolley fuse.

MASTER CONTROL.

26. THE MASTER CONTROL CIRCUIT (Fig. 492) is the circuit forming the path for the current from the bus line, through the master controller and the train cable, to the operating coils of the motor control apparatus.

27. THE ESSENTIAL PARTS of the master control of each car comprise the following apparatus:

TWO MASTER CONTROLLERS, which operate the motor control.

TWO MASTER CONTROLLER SWITCHES, used to cut off current from their respective master controllers when not in use.

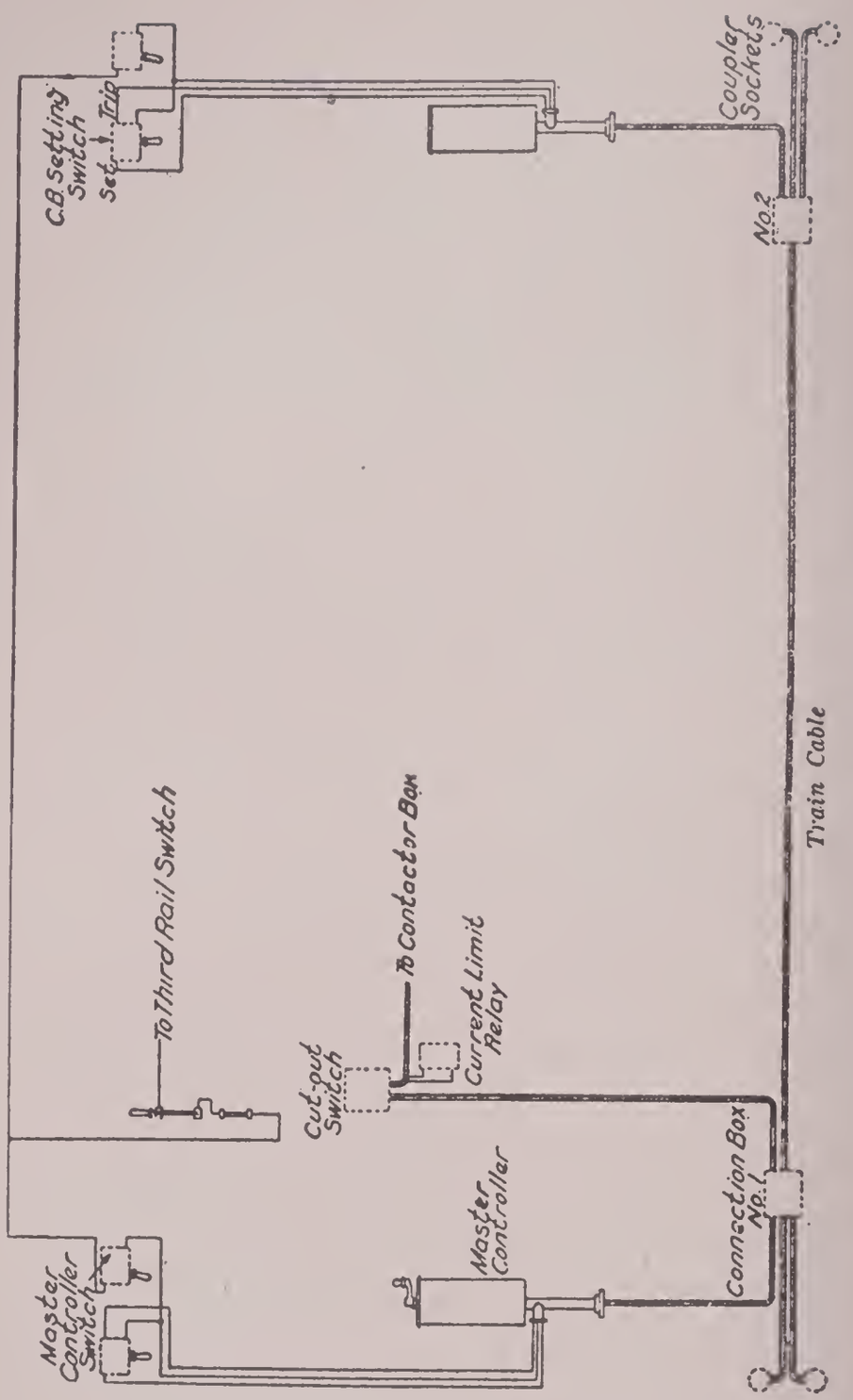
ONE MASTER CONTROL SWITCH, to cut off current to master controller and circuit breaker switches.

ONE TRAIN CABLE, which connects the master controllers to the motor control apparatus.

FOUR TRAIN CABLE COUPLER SOCKETS, to which the train cable jumpers are connected.

ONE TRAIN CABLE JUMPER, which connects the train cable between cars.

TWO TRAIN CABLE CONNECTION BOXES, where connection is made to master controllers, coupler sockets and seven-point cut-out switch.



GENERAL ARRANGEMENT OF MASTER CONTROL WIRING.

Fig. 492.

ONE SET OF RESISTANCE TUBES, which limit the current in the master control circuits.

ONE CURRENT LIMIT RELAY, which limits the rate of acceleration.

ONE POTENTIAL RELAY, which opens the master control circuit when power is cut off from the train.

ONE SEVEN-POINT CUT-OUT SWITCH, to disconnect motor control apparatus from train cable.

TWO CIRCUIT BREAKER SWITCHES, for setting and tripping circuit breakers.

CONTROL FUSES, which protect master control wiring against excessive current.

DESCRIPTION OF MASTER CONTROL APPARATUS.

28. THE MASTER CONTROLLERS, two in number, are located in the motorman's compartments, one at each end of the car.

The master controller (Fig. 493) contains a single movable contact cylinder and stationary fingers, mounted on an insulated support. The controller has a single handle for both forward and reverse direction of train movement. Four points are indicated on the cap plate for forward direction and two for reverse. The first point in either direction is called the "Switching" or "Lap" position; the second, "Full Series." The third point is called the "Parallel Lap" position, and the fourth, "Full Parallel."

The master controller governs the admission of current to the train cable for operating the reverser and contactors.

Fig. 493. Master Controller.

29. THE MASTER CONTROLLER SWITCHES, two in number, are located above each master controller, one at each end of the car.

Fig. 494. Master Controller Switch Without Fuse. Also Negative Control Switch on Locomotive.

The master controller switch (Fig. 494) is a pivoted switch mounted in an iron box and having a projecting handle. It is provided with a magnetic blowout. This switch is used to cut off current from its master controller when the latter is not in use. It also serves as an emergency switch in case of any failure of the master controller.

30. THE MASTER CONTROL SWITCH is located on the switchboard and is of the quick-break, knife-blade type.

The switch is used to cut off current from the master controller and the circuit breaker switches.

The normal position of the switch is open except when the train is being operated from a master controller on that car.

31. THE TRAIN CABLE is located in an iron pipe placed beneath the car.

The train cable is composed of seven conductors, each being covered with a different colored outer braid for identification. These conductors are attached to numbered plugs in the coupler sockets at the ends of the car. Branch cables run from connection boxes in the train cable to the master controllers, seven-point cut-out switch and coupler sockets.

The train cable is used to connect the operating master controller of the motor control apparatus of the car or train. The seven wires are used as follows:

No. 1. (Red) for accelerating or notching up.

No. 2. (White) for series connection of motors.

No. 3. (Green) for parallel connection of motors.

No. 4. (Green and White) for operating reverser one direction.

No. 5. (Yellow) for operating reverser other direction.

No. 6 (Red and Black) for tripping circuit breakers.

No. 7 (Black) for setting circuit breakers.

32. THE TRAIN CABLE COUPLER SOCKETS (Fig. 495), four per car, are attached to the under side of the car platform. These sockets are of malleable iron and contain a body of moulded insulation, into which are set seven bronze split plugs, one being attached to each conductor of the train cable.

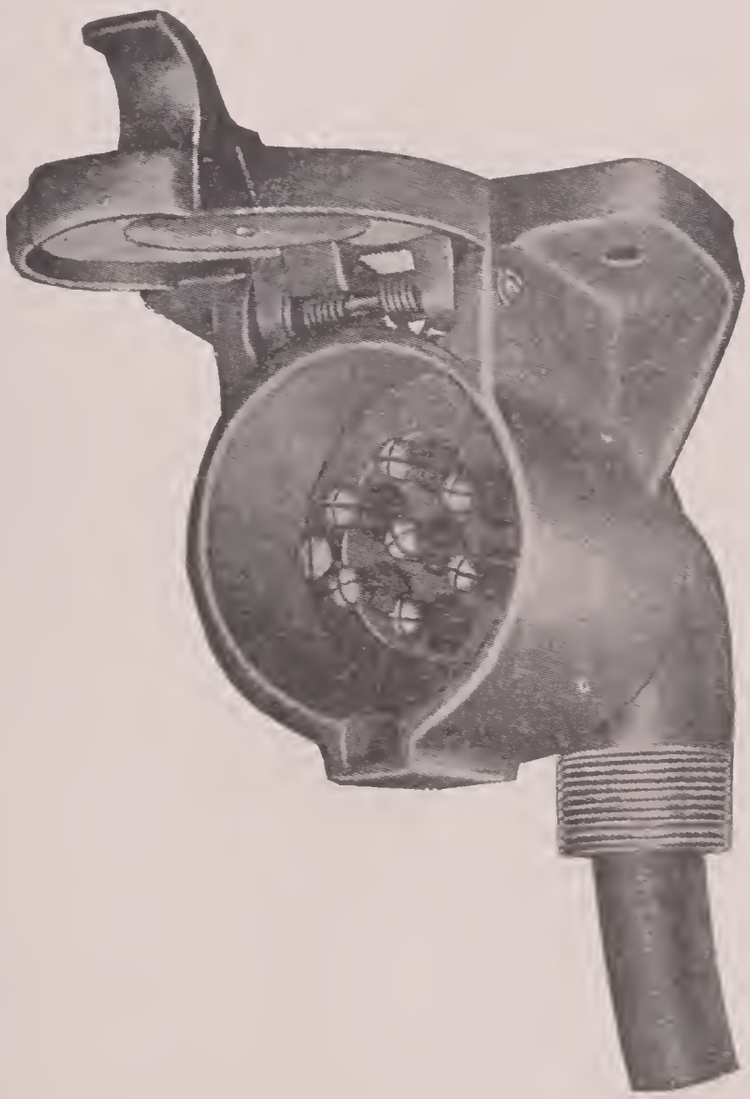


Fig. 495. Train Cable Coupler Socket.

Each socket is provided with a hinged cover adapted to hold the jumper plug in place and to prevent the entrance of dirt and moisture when no jumper is inserted.

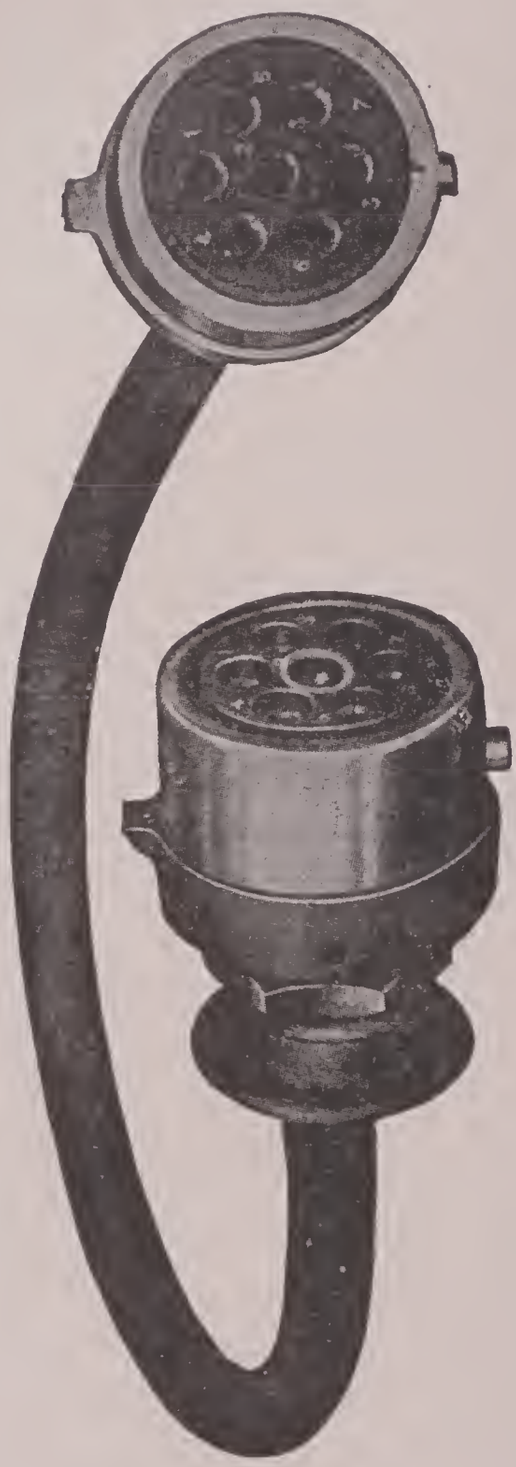


Fig. 496. Train Cable Jumper.

33. THE TRAIN CABLE JUMPER (Fig. 496) is used for connecting the train cables on adjacent cars. It consists of a short length of seven-conductor cable, with iron heads or plugs attached to the ends, each containing seven insulated contacts, one being secured to each conductor. The jumper heads fit into the coupler sockets on adjoining cars, and connect together their train cables.

34. THE TRAIN CABLE CONNECTION BOXES, two in number, are located beneath the car.

The train cable connection box (Fig. 497) is of iron and is used for making the connections from the master controller, circuit breaker, coupler sockets and cut-out switch to the train cable. Seven screw studs, which are held in an insulating board, are used for securing the terminals attached to the ends of the entering cables.

Conductors provided with the same colored covering are connected together, except at one connection box on each car, where Nos. 4 and 5, which operate the reverser, are crossed in order to obtain a direction of car movement to agree with the position of controller handle in either controller.

35. THE RESISTANCE TUBES are located in the contactor box, and consist of twelve tubes wound with resistance wire. They are used to regulate the current in the operating coils of the contactors.

36. THE CURRENT LIMIT RELAY (Fig. 498) is located on the switchboard. It consists of an electromagnet provided with two coils. The master control circuit passes through the upper coil and the main circuit for motor No. 1 through the lower coil. The master control circuit coil lifts the plunger for each step during acceleration and interrupts the contactor pick-up circuit.

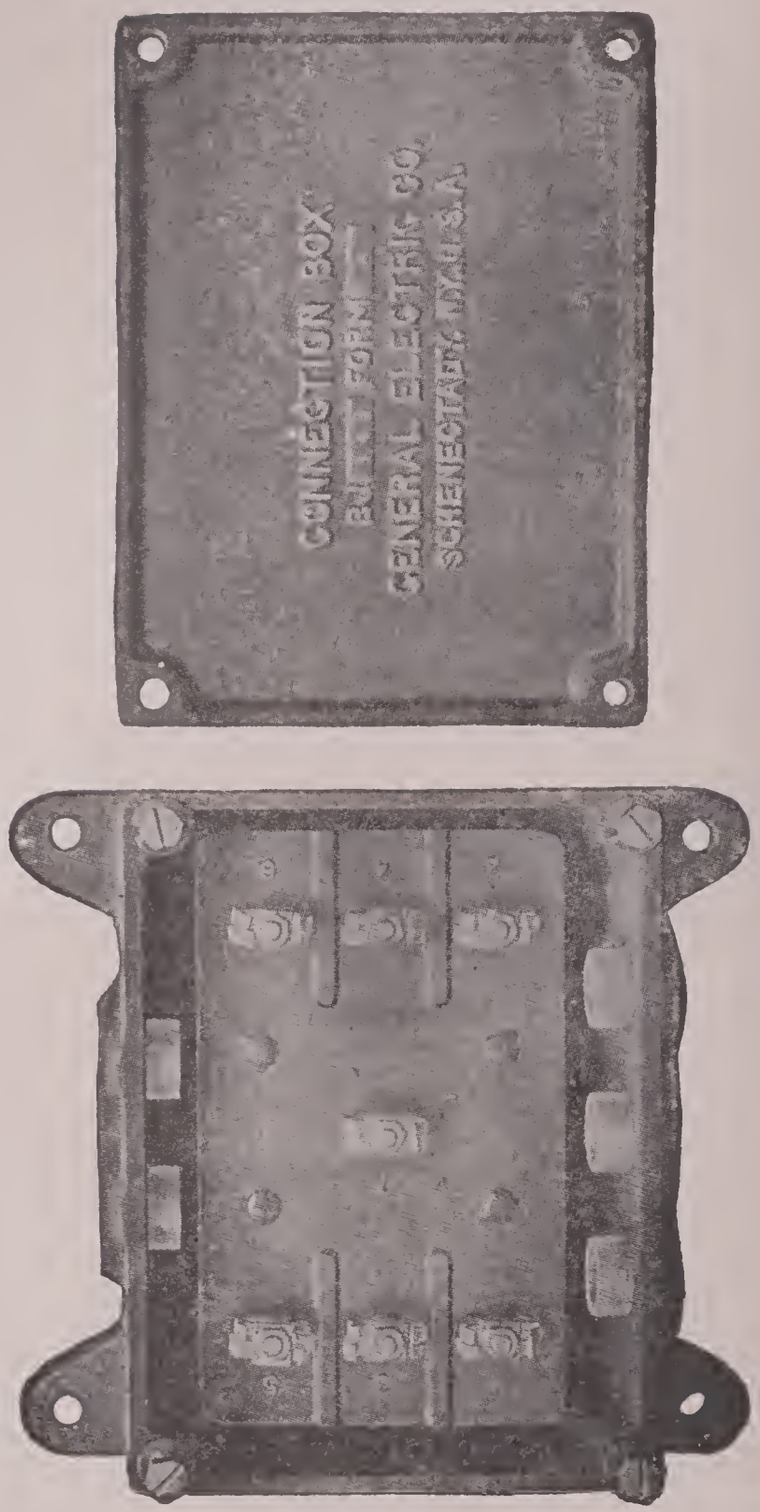


Fig. 497. Train Cable Connection Box.

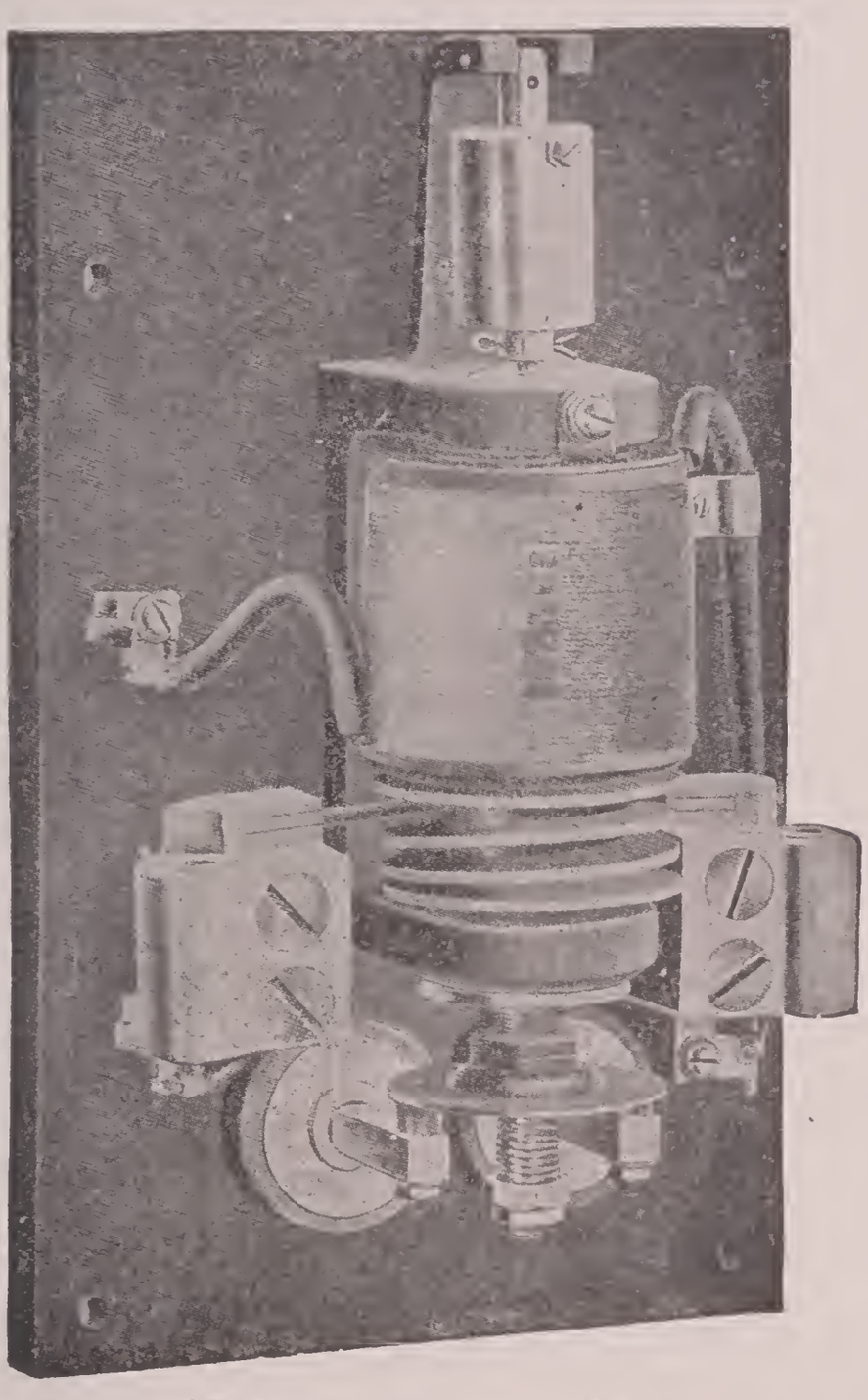


Fig. 498. Current Limit Relay.

If the current flowing through the main circuit coil is more than a certain amount the plunger is held in its upper position and cannot drop until the motor current has fallen to the desired amount.

The relay is provided for the purpose of producing an automatic control during acceleration.

37. THE POTENTIAL RELAY (Fig. 499) is mounted in the contactor box. It is similar to the current relay in construction, but is used for a different purpose. The relay has a coil which is connected between a point in the motor circuit, ahead of the first motor, and ground. If for any reason the motor current is interrupted on a car, this relay will open the master control circuit to the contactors on that car, causing them, in turn, to open. When current is restored to the car, the relay will again pick up and complete the master control circuit. The contactors will then pick up in regular succession, the same as if the motorman had shut off power and immediately turned the master controller handle on again.

38. THE CONTROL CUT-OUT SWITCH is mounted upon the switchboard. It consists of copper contacts, mounted on an insulated drum, and two sets of fingers fastened to the switchboard. It is provided for the purpose of disconnecting the master control circuit, to the contactors reverser and circuit breaker on the car, from the train cable.

39. THE CIRCUIT BREAKER SWITCHES, two in number, are located one above each master controller.

The circuit breaker switch (Fig. 485) is mounted in a cast iron box and consists of a pivoted blade, with a handle extending below the box.

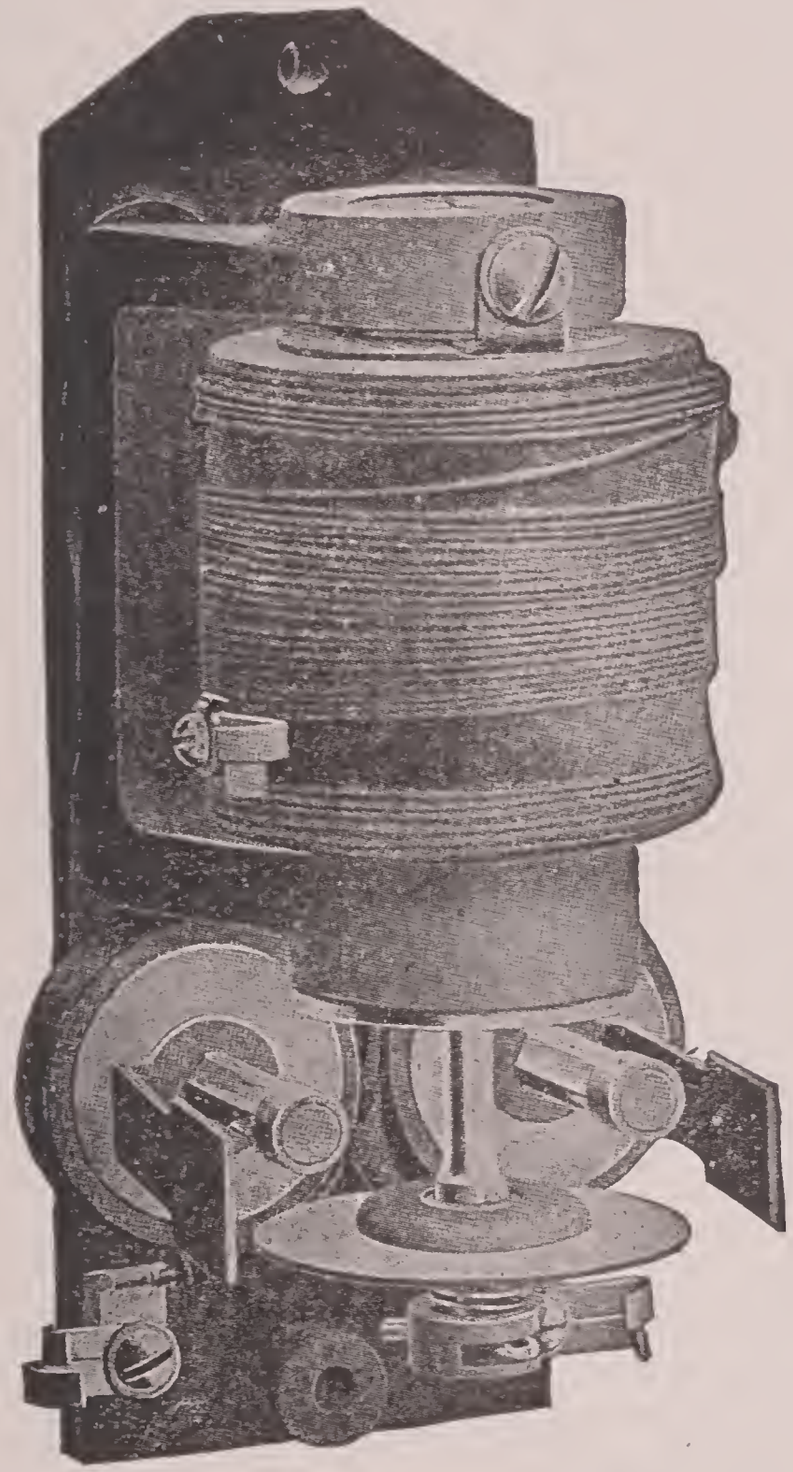


Fig. 499. Potential Relay.

The handle, when turned to the right, makes connection through a contact with the setting coils of the circuit breakers; when turned to the left, with the tripping coils of the circuit breakers. These positions are indicated by the words "On" and "Off" on the face of the box.

The normal position of the handle is vertical, and is held in this position by two springs.

40. CONTROL FUSES are mounted on the switchboard beside the control cut-out switch. A fuse is placed in each of the seven control circuits between the train cable and the cut-out switch.

41. THE SWITCHBOARD (Fig. 489) is located in the vestibule at the trailer end of the car, and has mounted upon it the following apparatus:

The THIRD RAIL SWITCH. (Paragraph No. 17.)

The SEVEN-POINT CUT-OUT SWITCH and FUSES. (Paragraph Nos. 38 and 40.)

The CURRENT LIMIT RELAY. (Paragraph No. 36.)

The MASTER CONTROL SWITCH AND FUSE. (Paragraph No. 30.)

SWITCHES AND FUSES FOR AIR COMPRESSOR, LIGHTS AND HEATERS.

EMERGENCY AIR BRAKE ATTACHMENT.

42. THE EMERGENCY AIR BRAKE ATTACHMENT for master controller (Fig. 493) consists of a main valve outside of the controller (Fig. 500), and a small pilot valve (Fig. 501) within it. The main valve

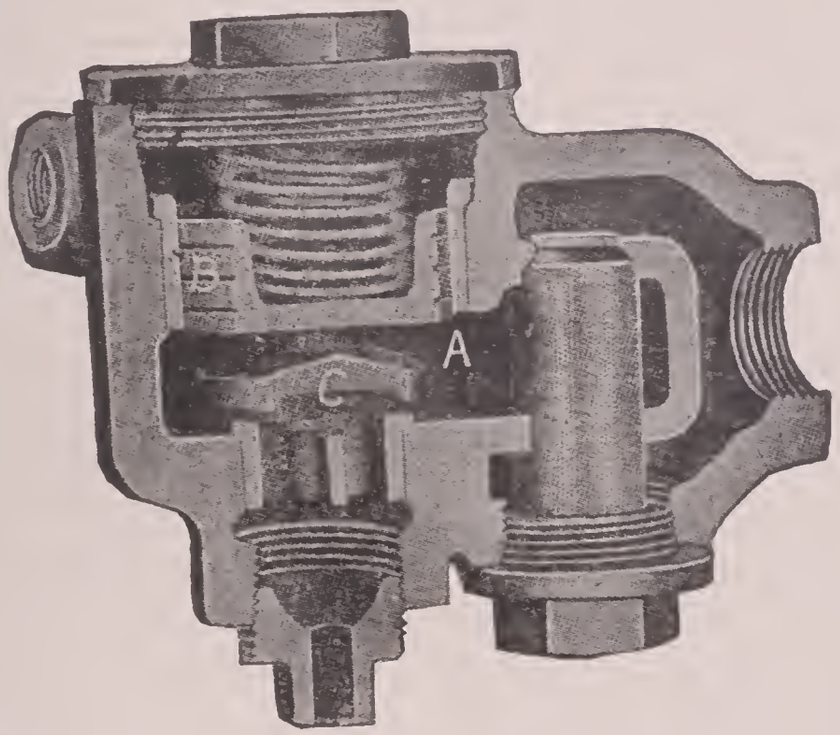


Fig. 500. Main Valve. Emergency Air Brake Attachment.

contains a chamber "A," divided into two parts by a piston "B" connected to a valve "C," exhausting to atmosphere. The lower part of the chamber "A" connects directly to the brake pipe. The upper part of "A" connects to the pilot valve through "F" and pressure in both parts is equalized by a small hole in the piston "B." When the pilot valve is opened, pressure in the upper part of the main valve is reduced, and the piston lifts, allowing the brake pipe to exhaust through a hole in the

bottom of the main valve to atmosphere. The pilot valve is opened by a loose collar on the cylinder shaft in the controller, which presses against the stem of the valve when the controller handle is at the "Off" position and the button released.

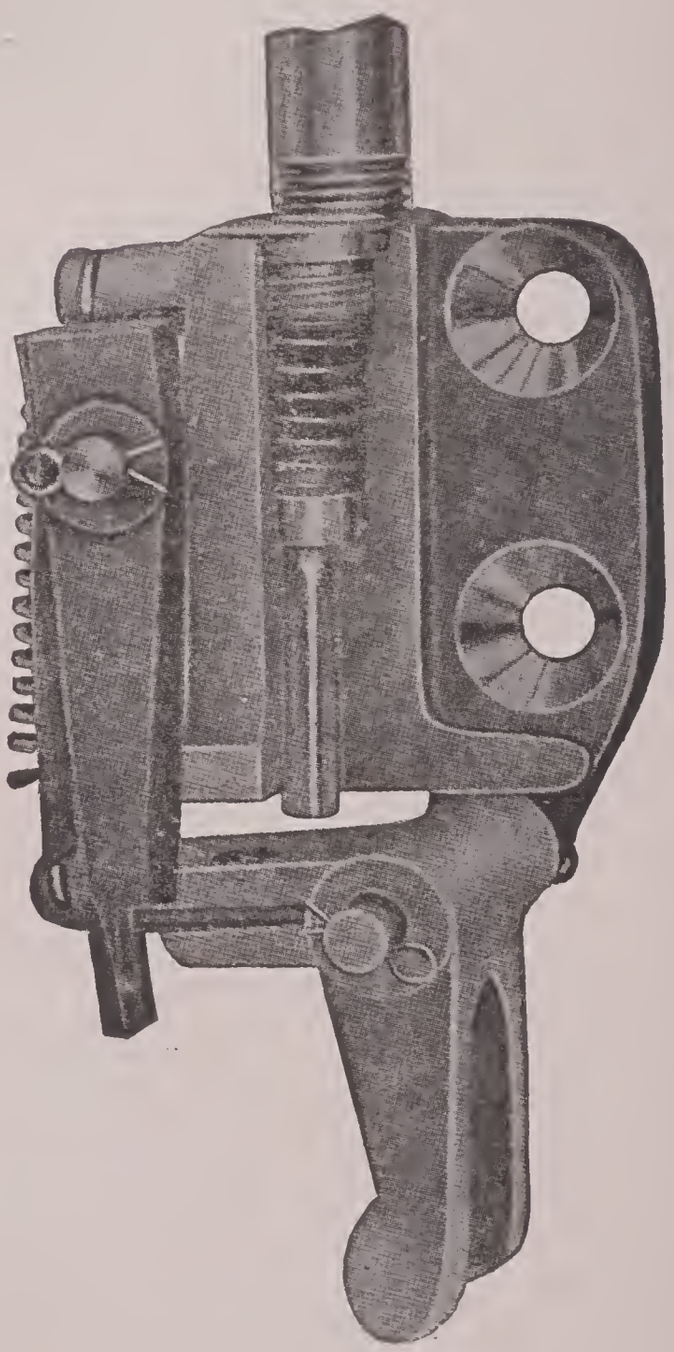


Fig. 501. Pilot Valve Emergency Air Brake Attachment.

TRAIN OPERATION.

43. GENERAL—The apparatus will be inspected and the train put in condition for operation by the inspectors; but the motorman will be held responsible for the operation of the apparatus while in his charge, and he should, therefore, familiarize himself with the location, use and operation of all apparatus on the cars, and should carefully follow the instructions below:

44. PREPARATIONS FOR STARTING—When the train is turned over to motorman, he should:

FIRST—Pass along the outside of train, carefully examining bus line and train cable jumpers between cars, to assure himself that all connections are properly made and that main switches are closed.

SECOND—Pass through the train, closing air compressor and third rail switches in each car, and opening master control switches in all cars except head car or car from which train is to be operated.

THIRD—Pass along outside of train again and satisfy himself that the air compressors are working properly.

FOURTH—Take position in the motorman's compartment at forward end of train and note the brake pipe pressure, which should be seventy pounds, close master controller switch. The circuit breakers should then

be set by moving the circuit breaker switch, over the master controller, to the "On" position—holding it there about one second to allow time for all circuit breakers to set.

FIFTH—Test the brakes as required by "Air Brake Instructions," making, upon request of the trainmen or inspectors, a full service application (twenty-pound reduction of pressure), holding them on until the trainmen or inspectors have examined the brakes on each car.

If the brakes are found in proper condition, trainmen or inspectors shall signal the motorman, from the rear of the train, who will then release the brakes.

The test is not complete until the trainmen or inspectors have re-examined the brakes, which should be done as quickly as possible, to see that they have released properly, after which the inspectors must report their condition to the motorman.

The train is now ready to be started.

45. TO START—Press down the button in the controller handle, insert the handle key and give it a quarter turn. The button must now be held down to prevent the pilot valve in the controller from operating and applying the brakes. Move the controller handle to the left as far as it will go, holding it there against the spring, which tends to return it to the "Off" position. The motor control will then notch up to full speed position by the automatic progression of the contactors, in successive steps, under the control of the current limit relay. In this

position it is not necessary to hold the button down to prevent application of the brakes.

46. COASTING—Hold the button down and move controller handle to "Off" position. In this position power will be shut off and the train may coast free.

47. SERVICE STOP—The service stop will be made by the air brake valve in accordance with the "Air Brake Instructions."

48. EMERGENCY STOP—The emergency stop may be made by releasing the controller handle, which will then return to the "Off" position, shutting off the power and applying the brakes.

49. TO START SLOWLY—Move the controller handle to the left to first point. In this position both motors on each car are connected in series with all resistance in circuit and the motor control will not "notch up" to higher speed.

50. TO INCREASE SPEED SLIGHTLY—Move the controller handle to the second point and quickly return it to first point. This operation results in the cutting out of one step of resistance, and may be repeated until all the resistance is cut out, thus slowly notching up under the control of the motorman and not automatically.

If the controller handle is left on the second point for a sufficient length of time, all resistance will be automatically cut out in successive steps, under the control of the current limit relay, until full series or half speed is reached.

51. RUNNING POSITIONS—The second and fourth notches are running positions, and the train should not be operated for more than a few minutes at a time with the controller handle on intermediate notches.

52. TO REVERSE—Move the controller handle to the right to the first point. The reverser will change the direction of train movement, and the motors will be connected in series with all resistance in circuit.

It is not possible to run above half speed in the reverse direction, and if higher speed is required, it can only be obtained by operating the master controller at the other end of the car or train.

TRAIN FAILURE.

53. A TRAIN FAILURE, that is, a failure of a train of one or more cars to move or to attain full speed, when the directions for train operation have been followed, may be due to one or more of the following causes:

FIRST—FAILURE OF POWER.

SECOND—DEFECT IN MASTER CONTROL CIRCUIT.

(a) Master control fuse blown or imperfect.
(b) Grounded train cable.
(c) Poor contact in master controller.
(d) Loose train cable jumper.

THIRD—DEFECT IN MOTOR CONTROL CIRCUIT.

(a) Circuit breakers open.
(b) Bus fuses blown.
(c) Loose or disconnected bus jumper.
(d) Main fuse blown.
(e) Shoe or trolley fuses blown.

FOURTH—FAILURE OF AIR BRAKES TO RELEASE.

FAILURE OF POWER.

54. A FAILURE OF POWER can be detected by closing the lighting switches; if lights burn, power is on.

DEFECT IN MASTER CONTROL CIRCUIT.

55. TO DETERMINE IF MASTER CONTROL CIRCUIT IS OPEN turn master controller handle to the first notch and open the master controller switch. The noise of slight arcing indicates that the master control circuit is closed and that the trouble is elsewhere. No arcing shows that the master control circuit is open and indicates that fuse is blown or imperfect. A black or charred spot in the center of the label, called a "Tell-tale," indicates that the fuse is blown and should be replaced. A fuse which shows no indication of being blown should be tested to detect faulty construction by removing a fuse from a lighting circuit and inserting the fuse to be tested. The lights burning indicate that the fuse is good, and it can then be replaced.

56. TO DETERMINE IF TRAIN CABLE IS GROUNDED, operate the master controller. If the master controller fuse blows, it indicates that one or more wires of the train cable are in contact with the ground, and the cable is said to be "grounded."

To locate a ground in the train cable, disconnect train cable on operating car from rest of train by removing train cable jumper from its socket on second car. If the fuse now blows, when the controller handle is operated, it indicates that the ground is either in the operating car or its train cable jumper.

To determine whether ground is in train cable or jumper, remove the jumper. If the fuse blows when the con-

troller is operated, the ground is in the car. If it does not blow, the ground is in the jumper, and a new one should be inserted. If the fuse does not blow when the jumper is disconnected from the second car, the jumper should be replaced, and the one between the second and third cars disconnected from its socket on the third car, and so on until the fault is located.

If the fault is found to be caused by a defective jumper, and if the train is not provided with an extra jumper, the jumper between the two last cars of the train should be taken to replace the defective one.

If the fault is found to be on the car and not in the jumpers, the seven-point control cut-out switch on that car should be turned to the "Off" position, and the test repeated. If the fuse still blows when the handle is operated, the fault is in the train cable. If the fuse does not blow, the ground is between the cut-out switch and the contactors, reverser and circuit breaker. If this is the case, the cut-out switch on the defective car should remain in the "Off" position, thus cutting out the fault as well as rendering the car inoperative, but in no way interfering with the train cable, and permitting the operation of other cars in the train, through the train cable in the usual manner.

If opening the cut-out switch does not remove the fault, that is, if the fault is in the train cable and the defective car is near the rear end, the train should be operated from the front car as usual, the defective car and those following being cut out by removing both train cable jumpers on that car; if at or near the head of the train, the train should be run from the following car, all cars ahead being cut out.

57. TO DETECT POOR CONTACT IN MASTER CONTROLLER, open the master controller switch, remove the cover from the controller and turn the handle slowly, noting if each finger makes good contact with the drum. If any contact is poor and cannot readily be readjusted by the motorman, he should run the train from the next car.

58. TO DETECT LOOSE TRAIN CABLE JUMPER, the trainmen should note if the contactors on each car are working while the train is accelerating. If there is a loose train cable jumper, all cars ahead of the jumper will operate; others will not. The motorman should be immediately informed if any car is not operating.

DEFECT IN MOTOR CONTROL CIRCUIT.

59. IF ONE OR MORE CIRCUIT BREAKERS OF A TRAIN BLOW when starting or running, return the controller handle to the "off" position and move the handle of the circuit breaker switch to the "on" position. If the circuit breakers again blow when the controller handle is operated, the brakes should be examined to see if they have released.

If the circuit breaker on any car repeatedly blows, the motorman should make an examination to see that it is properly adjusted. If the trouble is not with the circuit breaker, the car should be cut out by opening the seven-point cut-out switch on the switchboard and the main switch beneath the car.

Blowing of the circuit breaker is accompanied by a loud report.

60. AN OPEN CIRCUIT IN BUS LINE may be detected when the train is at a crossover and current cannot be obtained on operating car, although other cars of the train have current. This indicates that the bus line fuse or fuses are blown, or that a bus line jumper is loose or disconnected between the operating and adjacent cars.

The motorman should inspect the bus line jumpers, and if the trouble cannot be quickly remedied, he should go back to the first car having current and move the train through the crossover. The motorman should then return to the first car and proceed in the usual manner.

61. WHEN THE MAIN FUSE IS BLOWN, the motors will not operate, although the contactors may be in working order and the circuit breaker closed. This should occur very seldom, as it can only be caused by short circuit or grounding in the motors or motor circuits, which are usually protected by the quicker acting circuit breaker. This fuse should not be replaced on the road except to avoid serious delay to the service, as in the case of single cars. BEFORE RENEWING MAIN FUSE, OPEN THE MAIN SWITCH.

62. A SHOE FUSE MAY BLOW from short circuit, grounding of the car wiring on some part of the car or truck, or may be caused by a contact shoe on the car or train grounding, due either to being broken or from fouling or picking up something along the line. If it is necessary to replace a shoe fuse on the road so as to prevent delay to service, the motorman should open the third rail switch on the switchboard and insert the wooden paddles, provided for that purpose, between all shoes on that car that are in contact with the third rail.

63. A TROLLEY FUSE MAY BLOW from short circuit or grounding of the car wiring on the car or

truck, or because it has been overloaded by running in a train with other trolleys down and taking current for the whole train through the one fuse. If this latter has been the cause, the fuse should be replaced on the road if it is required to prevent delay to service. Before replacing the fuse, pull down both trolleys and open the trolley switch.

GENERAL DIRECTIONS.

64. IN CASE OF FIRE beneath any car in the train, the motorman should open all circuit breakers by moving the circuit breaker switch to "OFF" position. If this fails, he should open the main switch beneath the car and the seven-point cut-out switch on the switchboard.

65. IF SMOKE OR FIRE IS OBSERVED by the trainmen in any of the lighting or heater circuits within the car, they should IMMEDIATELY open the switch controlling the circuit, and extinguish the fire with SAND. NEVER USE WATER to extinguish a fire when power is "ON," as water is liable to increase the danger by causing further short circuits.

66. UNUSUAL NOISES in train movement should at once be located. To avoid delay the conductor or brakeman should stand beside the train while it is moved slowly. If noise is caused by brake rigging, the same should be tied up; if the noise is located within the motors, and the schedule permits it, the motors should be cut out by opening the seven-point cut-out switch on that car.

67. A BROKEN THIRD RAIL SHOE or shoe support should be broken completely off or tied up, whichever, in the judgment of the motorman, will cause the least delay. In either case, open the third rail switch on switchboard and insert wooden paddles between third rail and all contact shoes on the car. To break off remainder of shoe, use some tool with a wooden handle, as a hammer or ax. NEVER USE A CROWBAR OR COUPLER PIN FOR THIS PURPOSE.

68. TO STOP TRAIN WHEN AIR BRAKES FAIL, turn controller to first notch in reverse position. THIS SHOULD ONLY BE DONE IN CASE OF EMERGENCY AND TO AVOID ACCIDENTS.

69. CAUTION—Employes should exercise extreme care while working about or on car wiring. The switch controlling the circuit on which work is being done should always be open.

70. MOTORMEN MUST REPORT at the end of each trip, on the regular form provided for the purpose, all detentions and reasons for such detentions and any defects in electrical, air and signal apparatus.

The New York Central is now operating a portion of the 289 miles of track which will soon be entirely operated by electricity.

Their equipment which is now all in use consists of 125 motor cars each containing 400 H. P. of electric motors and 35 locomotives each of 220 H. P. with large overload capacity. Each locomotive will develop 2500 H. P. before blowing fuses, and can sustain that power for several minutes.

Recently a train of 9 Pullmans went dead on a 0.5% grade in the tunnel, on account of engine trouble. One of the electric locomotives coming up behind with 7 coaches, at once coupled on and started the whole combination of itself, a dead locomotive and 16 cars, the whole weighing about 1000 tons. It drew the whole up a 1% grade about half a mile long at good speed and landed them at the Mott Haven yard.

The motor car trains make a maximum speed of 52 miles per hour.

The locomotive trains make a maximum of about 66 miles an hour with regular trains.

SUBURBAN MOTOR CARS.

A.—General.

1. Sprague-General Electric Type "M" control system, as supplied to the Suburban Motor Cars of the New York Central & Hudson River Railroad Company, comprises two distinct sets of controlling apparatus, namely, the main or motor control and the master control.

2. Each motor car is equipped with a set of motor control apparatus which serves to carry current from the third rail through the motors to ground, forming different combinations of motors and cutting out resistances in starting that particular car. Each motor circuit is local, being confined to its respective car.

3. Every motor car in the train is equipped with master control apparatus, the office of which is to operate the motor control. An important feature of the master control is the train cable, comprising seven conductors running the entire length of the train with suitable couplers between cars. On every motor car a connection is made from this cable to the motor control apparatus on that car. At every cab connection is made from the train cable to a master controller. Consequently, any master controller on a train can energize the entire train cable and operate all the motor control apparatus connected to it.

B.—Motor Control.

4. The motor control on each car consists of the following apparatus:

A set of Contactors mounted in a box.
A Reverser.
A set of Rheostats.
A Circuit Breaker
A Main Fuse.
A Main Switch.

5. In addition to these pieces of apparatus there are four third rail shoes with the necessary main cables connecting them to the control apparatus on the same car. There is also a main cable extending the whole of the train and provided with couplers between cars which connects the third rail shoes throughout the train together. This cable is termed the bus line.

6. From the third rail shoes the main circuit is carried to the main switch on the panel board and from there through the main fuse and circuit breaker to the contactors.

7. THE CONTACTOR (Fig. 480) is a switch, the movable portion of which is operated by an electro-magnet which receives line current from the master controller through the train cable. Where the main contact is made two heavy copper tips are provided. These two contact tips are inclosed in an arc chute, and a powerful magnetic blowout is provided having poles extending along two sides of the arc chute for promptly extinguishing the arc formed in breaking the circuit.

8. A CONTACTOR BOX (Fig. 481) is provided for holding the set of fifteen contactors. This box is of iron, heavily lined with asbestos and other insulating materials for preventing short circuiting. This box is provided with two sheet-iron covers, which can be readily dropped down by releasing suitable catches when it is desired to inspect the contactors. These contactors are supported in the box by means of insulated bolts.

9. THE REVERSER (Fig. 482) is a multiple switch, the movable part of which is a rocker arm operated by two electro-magnets, one being used for each direction. These coils are energized by current from the master controller circuit, and the connections are such that only one coil can receive current at one time. Wires from the motor armatures and fields are connected to the fingers of the reverser, and, by means of contact pieces on the rocker arm insulation, the proper connections of armatures and fields are established for producing forward and backward movement of the car. The reverser is installed in a metal box provided with a hinged cover, held in place by a swing latch.

10. THE MOTOR CONTROL RHEOSTAT (Fig. 483) is made up with a number of cast-iron grids mounted in, and insulated from, an iron frame. These rheostats are used to regulate the supply of current to the motors while the car is accelerating. Cables connect the various rheostats to different contactors, so that the latter may cut out sections of resistance as required.

11. THE CIRCUIT BREAKER (Fig. 484) is similar in construction to a contactor, but designed to carry and break the full current taken by a car. It is closed by means of an electro-magnet which is energized by a setting switch located in the motorman's cab. The circuit

breaker is tripped automatically when excessive motor current flows through its series tripping coil. The motorman may also trip the circuit breaker by moving the combined setting and tripping switch handle to "off" or trip position.

12. THE MAIN FUSE (Fig. 486) is a thin copper ribbon contained in a box composed of insulating material. Sheet-iron pole pieces partially surround the insulation and provide a magnetic blowout for expelling the arc formed when the fuse melts. The fuse will ordinarily not melt and open the circuit, as the time required for this is greater than that taken by the circuit breaker to trip. A continued excessive current will, however, melt the fuse.

13. THE MAIN SWITCH is a knife blade quick break switch, located on the panel, and is used to cut off the supply of current through the main fuse, circuit breaker, contactors and motors. This switch should not be opened while the motors are taking current, except in an emergency. It should, however, always be opened before the main fuse, circuit breaker or contactors are examined. Fig. 502.

14. THE BUS LINE COUPLER SOCKET (Fig. 490) composed of a body of molded insulating material containing a large split plug contact. Supporting feet of malleable iron are secured to this insulating body for attaching to the under side of the car platform. A hinged lid at the front of the socket is also provided, having the two functions of holding the coupler plug in place and excluding dirt and water when the jumper is not inserted.

15. THE BUS LINE COUPLER OR JUMPER (Fig. 491) consists of a short section of flexible insulated

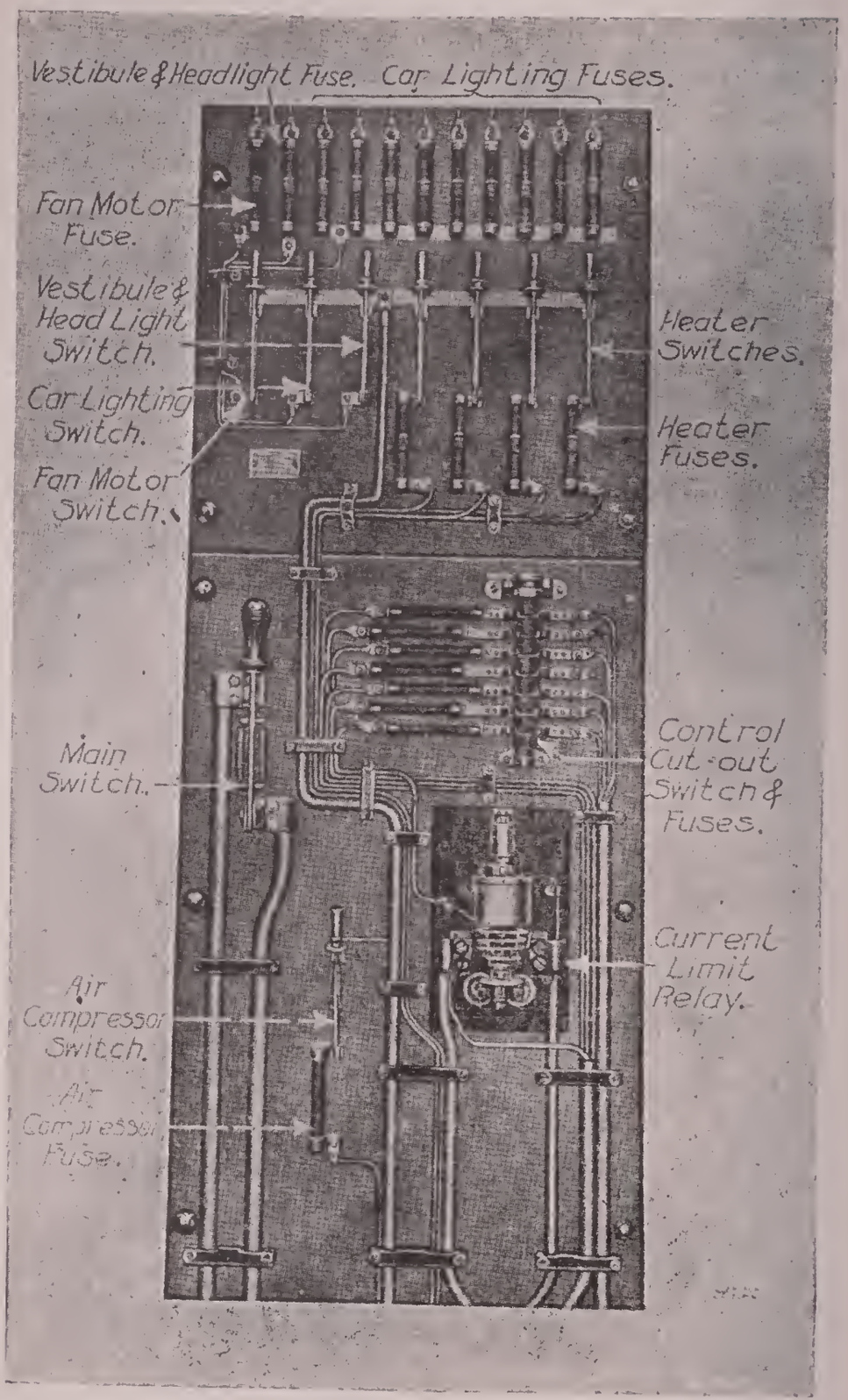


Fig. 502. Switchboard—New York Central Equipment.

cable with a plug attached to each end. But one jumper is required for connection between two adjacent cars, the additional sockets being provided so that cars may be turned end for end, or coupled, in any desired relation.

16. THE BUS LINE FUSE is identical with the main fuse. Two of these are provided, as shown on diagram, for protecting the bus line.

17. THE BUS LINE JUNCTION BOX is provided for connecting the ends of the bus line cable. The box is composed of cast iron and contains an insulating board, to which is secured a single stud bolt for holding the cable terminals.

18. THE SHOE FUSE BOX is very similar to the main and bus line fuse boxes, but is adapted for attachment to the wooden third rail shoe beam.

C.—Master Control.

19. THE MASTER CONTROL APPARATUS comprises the following for each car:

Two Master Controllers.
Two Master Controller Switches.
Train Cable.
Four Train Cable Coupler Sockets.
One Train Cable Coupler or Jumper.
Two Train Cable Connection Boxes.
Current Limit Relay.
One Potential Relay.
One Cutout Switch.
Two Circuit Breaker Setting and Tripping Switches.
Control Fuses.

20. THE MASTER CONTROLLER (Fig. 493) contains a single movable contact cylinder and stationary fingers mounted on an insulated support. The function of the master controller is to supply current at the will of the motorman to the train cable for operating the reverser and contactors. The controller has a single handle for both forward and reverse direction of train movement. Four points are indicated on the cap plate for forward direction and two for reverse. The first point in either direction is called the "switching" or "lap" position, the second "full series." The third point forward is called the "parallel lap" position and the fourth the "full parallel."

21. THE MASTER CONTROLLER SWITCH (Fig. 503) is located over the master controller and is used for admitting current to the master controller at the operating end of the train. A suitable enclosed fuse is located within the switch box to protect the master control circuit.

22. THE TRAIN CABLE is composed of seven conductors, each being covered with different colored braiding for identification. These conductors are attached to numbered plugs in the coupler sockets at the ends of the car and branch wires extend to the master controllers.

These seven wires are used as follows:

No. 1. For accelerating or notching up.
No. 2. For series connection of motors.
No. 3. For parallel connection of motors.
No. 4. For operating reverser one direction.
No. 5. For operating reverser other direction.
No. 6. Tripping circuit breakers.
No. 7. Setting circuit breakers.

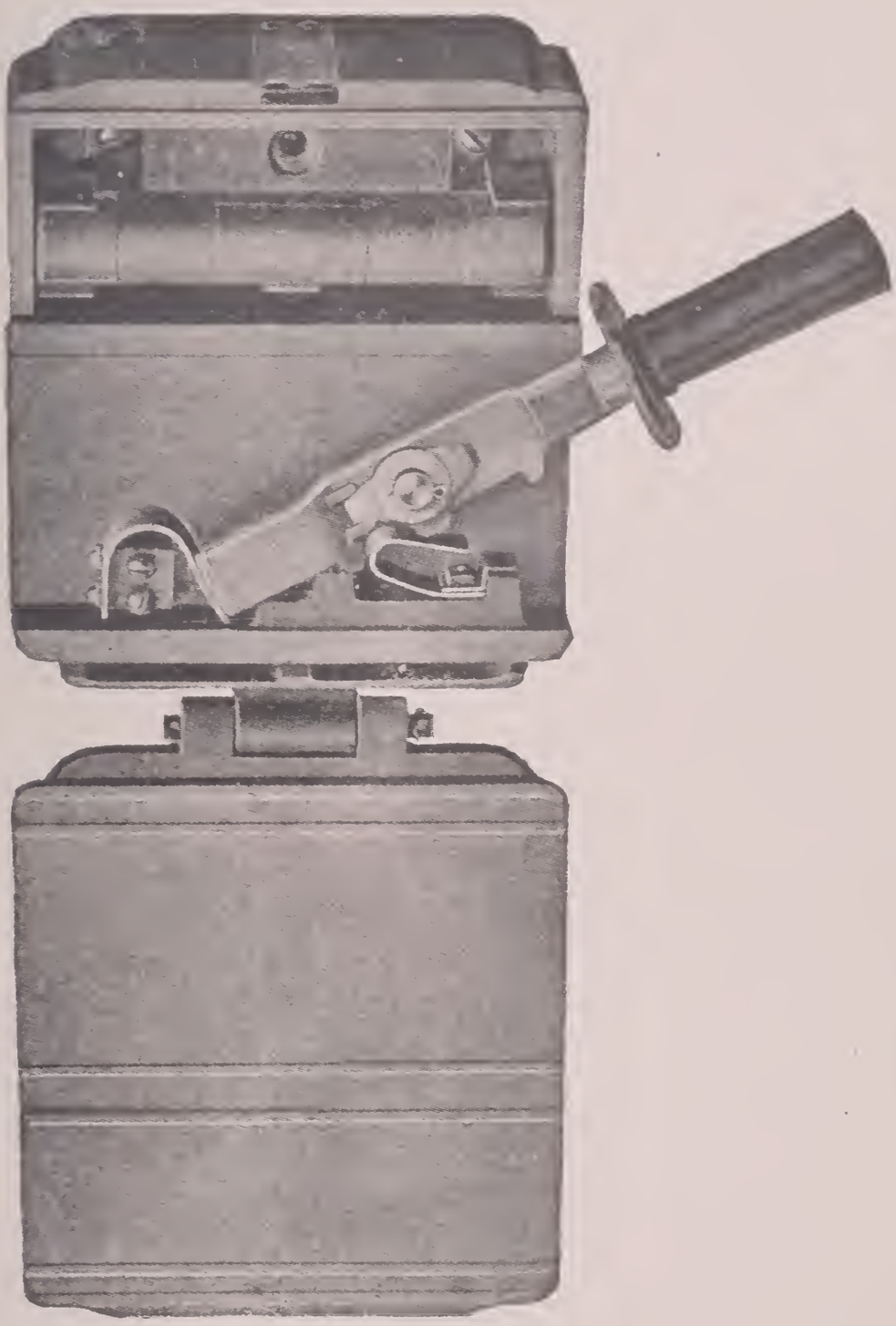


Fig. 503. Master Controller Switch; Pump Switch; also Main Sander Switch on Locomotive.

In order to secure the proper protection from injury the train cable is carried in iron conduit.

23. THE TRAIN CABLE COUPLER SOCKET (Fig. 495) is attached to the under side of the car platform. This socket is of malleable iron and contains a molded insulation body into which are set seven bronze split plugs, one being attached to each conductor of the train cable. The socket is provided with a hinged cover, adapted to hold the jumper plug in place and to prevent the entrance of dirt and moisture when no jumper is inserted.

24. THE TRAIN CABLE COUPLER, OR JUMPER (Fig. 496) is used for connecting the train cables on adjacent cars together. It consists of a short length of seven-conductor cable, with heads or plugs attached to the two ends, each containing seven insulated contacts, one being secured to each conductor. The jumper heads fit into the coupler sockets on two adjoining cars, and connect their train cables together.

25. THE TRAIN CABLE CONNECTION BOX (Fig. 497) is used for making the connections from master controller, circuit breaker setting and tripping switches and coupler sockets to the train cable. Seven screw studs, which are held in an insulating board, are used for securing the terminals attached to the ends of the entering cables. Conductors provided with the same colored covering are connected together, except at one connection box on each car, where the two wires Nos. 4 and 5, which operate the reversers, are crossed in order to obtain the direction of car movement to agree with position of controller handle in either controller.

26. THE CURRENT LIMIT RELAY (Fig. 498) is provided for the purpose of producing an automatic

operation of the control. The control circuit passes through the upper coil and the main circuit for one motor through the lower coil. The control circuit coil lifts the plunger for each step during acceleration and interrupts the contactor pick-up circuit. If the current flowing through the main circuit coil is more than a certain amount the plunger is held in its upper position and cannot drop until the motor current has fallen to the desired amount. This relay is mounted on the panel board.

27. THE POTENTIAL RELAY (Fig. 499) is somewhat similar to the current limit relay in construction, although it is used for a different purpose. This relay has a coil which is connected between the motor circuit, before reaching the first motor, and ground. If for any reason the motor current is interrupted on a car, this relay will open the control circuit to the contactors on that car and the contactors will drop open. When current is restored to the car the relay will again pick up and complete the control circuit. The contactors will then pick up in regular succession the same as if the motorman had shut off power and immediately turned the master controller handle on again. This relay is mounted in the contactor box.

28. THE CONTROL CUT-OUT SWITCH (Fig. 502) is provided for the purpose of disconnecting the control circuits of the contactors, reverser and circuit breakers on a particular car from the train cable. This switch is located on the panel board at one end of the car where it can be easily reached.

29. CIRCUIT BREAKER SETTING AND TRIPPING SWITCH (Fig. 485). This switch is provided with a single handle having springs to return it to a

mid-position. Moving the handle in one direction makes connection from the master controller switch through the train cable to the various setting coils of the circuit breakers. Moving the handle in an opposite direction completes a circuit from the master controller switch through train cable to the tripping coils on the various circuit breakers throughout the train. This switch is conveniently located above the master controller, and the two operating positions for the handle are indicated by "on" for setting and "off" for tripping.

30. CONTROL FUSES (Fig. 502) are placed in the circuits between cut-out switches and operating coils of contactors, reverser and circuit breaker on each car for providing suitable protection. These fuses are located on the panel switchboard in an accessible place.

31. EMERGENCY AIR BRAKE ATTACHMENT.—The emergency air-brake attachment for master controller (Fig. 500) consists of a main valve outside of the controller and a small pilot valve (Fig. 501) within it. The main valve contains a chamber "A," divided into two parts by piston "B," connected to a valve "C" exhausting to atmosphere. The lower part of the chamber "A" connects to the pilot valve through "F," and pressure in both parts is equalized by a small hole in the piston "B." When the pilot valve is opened pressure in upper part of main valve is reduced and the piston lifts, allowing the train line to exhaust through a hole in the bottom of the valve to atmosphere. The pilot valve is opened by a loose collar on the cylinder shaft in the controller, which presses against the stem of the valve when controller handle is at the "off" position and the button released.

D.—Train Operation.

32. Before attempting to start a train the motorman should close the air-compressor switches located on the panel boards of the various cars and wait until the train line and reservoir are properly charged, following the air-brake instructions in regard to testing brakes.

33. He should then see that all main switches are closed and all master controller switches open, with the exception of the one near the controller, which he is to operate. He should also move the circuit-breaker switch to its "on" position, allowing about a second for the circuit breakers throughout the train to close.

34. To start the train press down the button in the controller handle, insert the handle key and give it a quarter turn. The knob in the top of the handle must now be held down to prevent the pilot valve in the controller from operating and applying the brakes.

35. If it is desired to have the control notch up to the maximum speed position, the operating handle should be moved at once to the left as far as it will go and held there against the spring pressure tending to return it to the "off" position. While in any running position the knob in the handle need not be held down, as the air brakes will not be applied automatically unless the controller handle is at its "off" position and the knob released.

36. When the controller is at the full "on" position control current passes from the master controller switch through the master controller to the train cable and thence to the various cars of the train. If the reversers are not thrown to the position corresponding with the move-

ment of the controller handle current will first pass through the proper operating coil of the reversers to ground. After the reversers have reached the correct position interlocking contacts on them cut off circuit to ground and establish one through four contactor coils. Simultaneously current passes from the master controller through another train wire (called the series retaining or No. 2 wire) to a fifth contactor coil, and this contactor, in conjunction with the other four, produce the first or switching point. At the same time a third wire (the notching or No. 1 wire) is energized and the circuit is established through the current limit relays pick-up coil and the resistance contactors, so that the progressive steps are started. Each of these resistance contactors in picking up prepares the control circuit, by means of interlocking switches located on the bottom of contactors, for the next step; it also cuts out the contactor from the "notching" circuit and connects it in the "retaining" circuit. The current limit relay, in lifting, opens the notching circuit and thereby prevents the contactor for the succeeding step from lifting at once. When the current in the motor circuit coil has reached a sufficient amount to prevent the current limit relay from dropping, this notching circuit is not immediately completed and the progression is temporarily arrested. When the relay again drops another contactor is closed, and the same action is repeated until the last or full parallel is reached.

37. The main or motor current flows from the third rail shoes to the main switch, through the circuit breaker and main fuse to the contactors, then through the reverser and No. 1 motor to a set of rheostats, then through another set of rheostats and No. 2 motor to ground. The motors are now in "series" with all resistance in

circuit and the car starts slowly. On succeeding steps until the full series position is reached, the rheostats are cut out in five more steps by the automatic operation of the contactors. After the full series position has been reached a "Bridge" connection is established by the contactors, and the motors are then connected in parallel with rheostats connected in series with each. The same automatic "notching up" of the contactors continues, the controller handle being in the fourth forward position, until all the resistance is cut out of circuit by means of the contactors, and the motors are in full parallel.

38. If it is desired to operate the train at low speed, as in switching, the master controller handle should be moved to the left for forward direction, to the first point only. On this point the full resistance will be in circuit, while the two motors in series and the control will not "notch up." If it is necessary to slightly increase the speed the controller handle should be moved to the second point to start the automatic progression of the contactors through the resistance steps and quickly returned to the first or lap position. The notching up will be arrested, but the contactors which have picked up and cut out more resistances will remain closed. This manipulation of the controller handle may be repeated and a slow acceleration obtained when it is necessary. If the handle is left on the second point for a sufficient time all of the resistance will be automatically cut out of the motor circuit in successive steps under the control of the current limit relay until full series, or half speed, is reached.

39. When it is necessary to reverse the direction of the train movement the master controller handle should

be turned to the right. The first point in this direction is a switching point, similar to first point forward, and the train will move slowly without materially increasing its speed. If a higher speed is desired the handle should be moved to the second point and the automatic notching started for cutting out the resistance. It is possible to obtain only half speed in the reverse direction, as the second point leaves the motors in series relation.

40. Returning the master controller handle to the "off" position cuts off the supply of current to the train cable and contactors, and the latter therefore drop out and open the main circuit through the motors. Should the motorman from any cause remove his hand from the controller handle while it is at an "on" position a spring will return it to the "off" position and thereby automatically cut off power from the train and apply the air brakes. When the motorman turns to the "off" position it is necessary to hold down the knob in the controller handle to prevent the application of air brakes.

41. The controlling cut-out switch disconnects the operating parts of contactors, reverser and circuit breaker on the car from the train cable, but does not affect the operation of the rest of the train, although the car may be the one from which the train is being operated.

42. The arrangement of apparatus is such that the train may be operated in either direction from any master controller in the train. It is necessary, however, in order to operate in a reverse direction at full speed, to operate from a master controller at the end of a car toward the direction in which the train is to be moved.

43. Should the train break apart the control couplers will pull out, cutting off current from the train cable on the section of train behind the break. This drops out all

the contactors on the rear section, while the front section continues under the control of the motorman.

44. The control connections for the reverser are so arranged that unless the reverser is at the proper position current is cut off from the contactors, and, consequently, the motors on that car receive no current. When the reverser is in the correct position it is electrically locked and cannot be operated while the motors are taking current.

45. The wires of the master control circuit are all protected from damage due to excess current by means of small fuses. In case of electrical trouble within the master controller, train cable, couplers or connection boxes, the single fuse in the master controller switch will protect them. In case of trouble in the control circuit at contactors, reverser or circuit breaker, the fuses on the panel board will protect the circuit.

ELECTRIC LOCOMOTIVES.

A.—General.

46. The general remarks pertaining to the Sprague General Electric type "M" control, as applied to the Suburban Motor Cars (see paragraphs 1, 2 and 3), will also apply to the electric locomotive control, except that the train cable in the locomotive control has twenty wires, seventeen of which are connected to the master controller and to the motor control apparatus. Of the remaining three wires two are used for the sander device and one is an extra. This control, in the same way as on the Suburban Motor Cars comprises two distinct sets of circuits, namely, the main or motor control circuits and the master control motor circuits, the former being governed by the latter. Each locomotive has four motors, the control being arranged for operating the motors first, all in series, then in series parallel, and then in parallel relation. The two ends of locomotive are designed the "A" end and the "B" end, the main switch being located on the "B" end.

B.—Motor Control.

47. THE MOTOR CONTROL on each locomotive consists of the following apparatus:

Contactors.
Reversers.
Rheostats.
Main switch.
Main motor cut-out switches.
Individual motor fuses.

In addition to these pieces of apparatus there are four sets of third-rail contact shoes (two shoes in each set) and two overhead contact shoes, with the necessary main cables connecting them to the control apparatus on the locomotive. There is also a main cable extending through the locomotive terminating with couplers at the ends, so that the third-rail shoes and the overhead shoes of any two or more locomotives may be connected together. This cable is termed the Bus Line. The circuits from the contact shoes (both third rail and overhead) are protected by fuses, a set of two fuses in multiple being located near each shoe to protect the circuit of that shoe. From the third-rail shoes or from the overhead shoes the main circuit is carried through the respective fuses of each to the main switch and through the motor fuses to the contactors and thence to motors.

48. THE CONTACTOR (Fig. 504) is an electro-magnet switch (see general description under paragraph 7, Suburban Motor Cars), with two contact arms and sets of contacts in multiple operated by one plunger. There are 43 of these contactors which are located in the end compartments of the cab, one group on each side of each end compartment. The contactors are suspended by insulating bolts from channel iron supports. The contactors are numbered progressively around the cab, No. 1 being the nearest the No. 1 reverser. Each contactor has a plate with its number, which is attached in front above the arc chute.

49. REVERSER (Fig. 505) (see general description, paragraph 9, Suburban Cars). There are two reversers; one in each end compartment. The No. 1 reverser, which is on the main switch end of the locomotive, has the armature and field leads of the two motors

on that end connected to the studs of its contact brushes. The connections of armatures and field leads for producing forward and backward movement of locomotive are established by means of copper bars pressed against spring contact brushes, through a toggle mechanism.

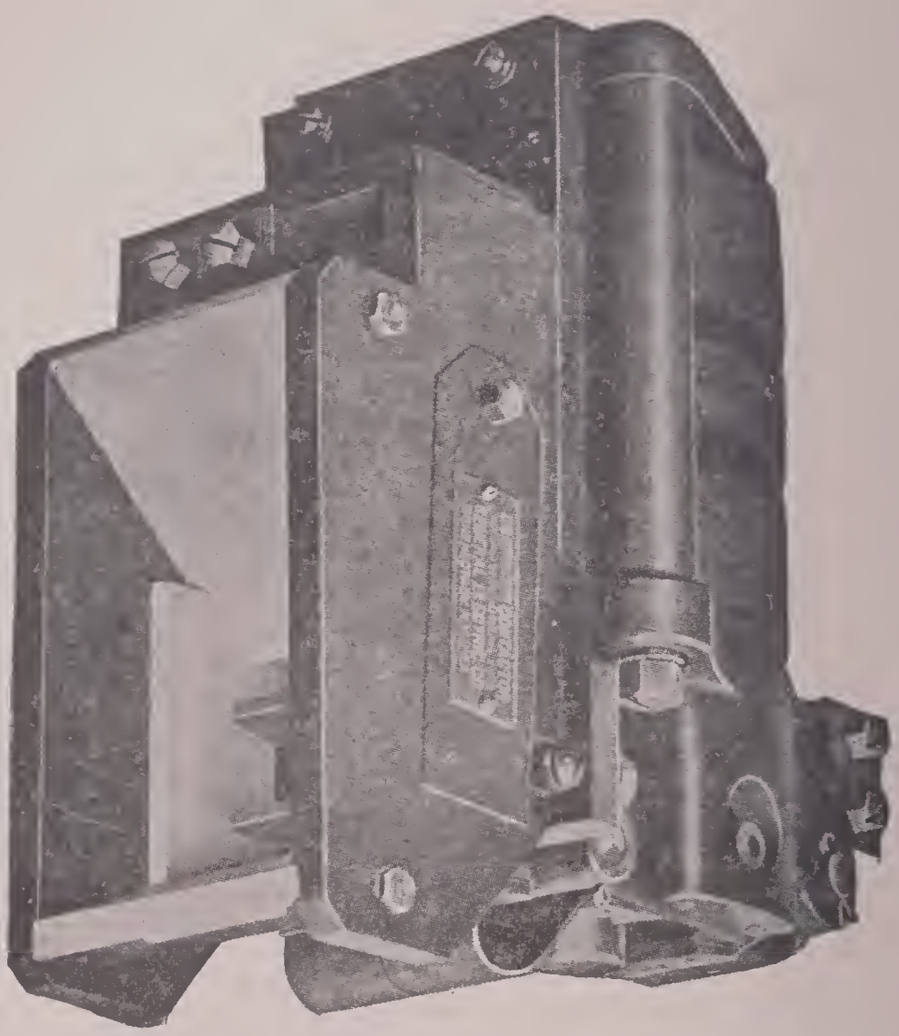


Fig. 504. Contactor for Large Current

50. THE MOTOR CONTROL RHEOSTATS (Fig. 506) are similar to those described under paragraph 10, Suburban Cars. These rheostats are located in four groups on the floor in end compartment of cab, under the contactors.

51. THE MAIN SWITCH (Fig. 507) is a knife-blade quick-break switch, with a lower mechanism for operating. The switch itself is enclosed in a box, lined

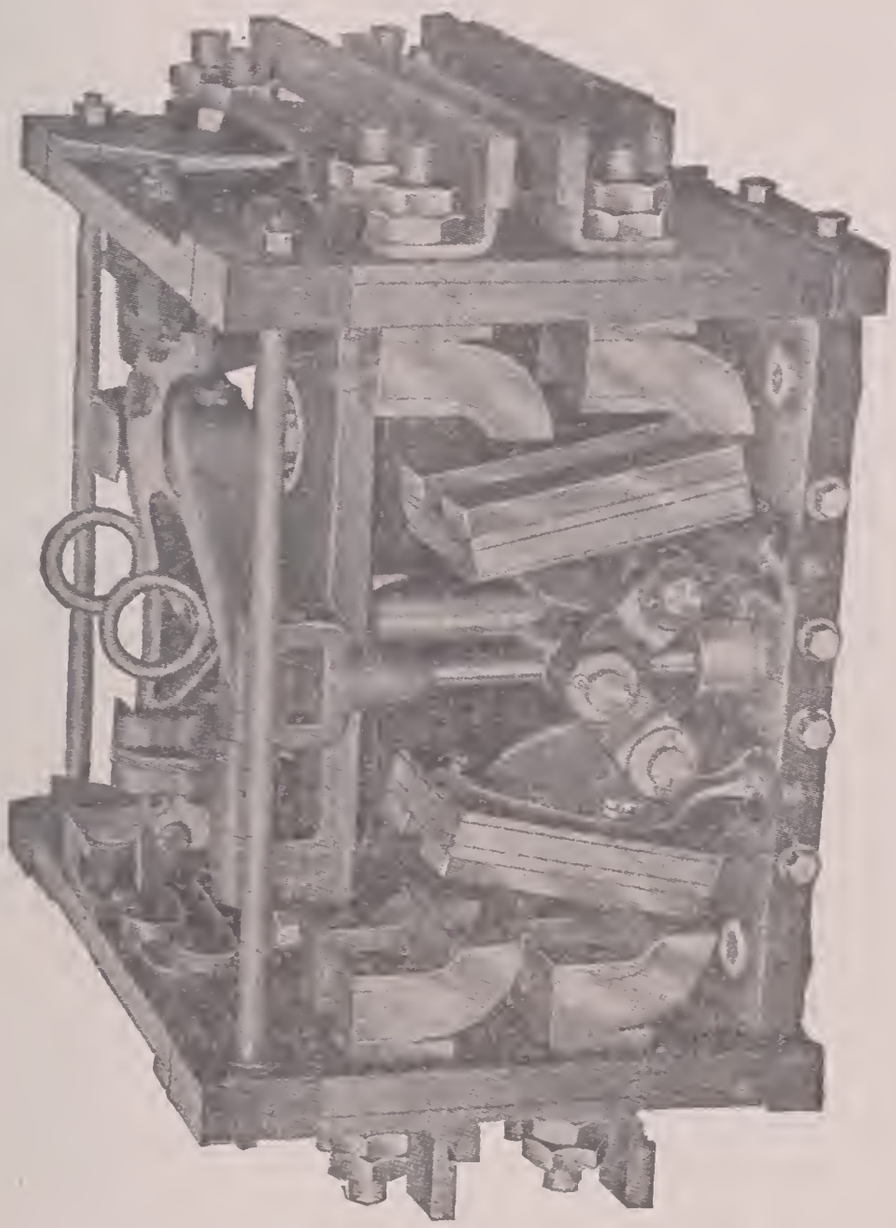


Fig. 505. Reverser for Locomotive.

with fireproof insulation, the handle for operating being located outside the box, where it is readily accessible. This switch is located in "B" end compartment of cab.

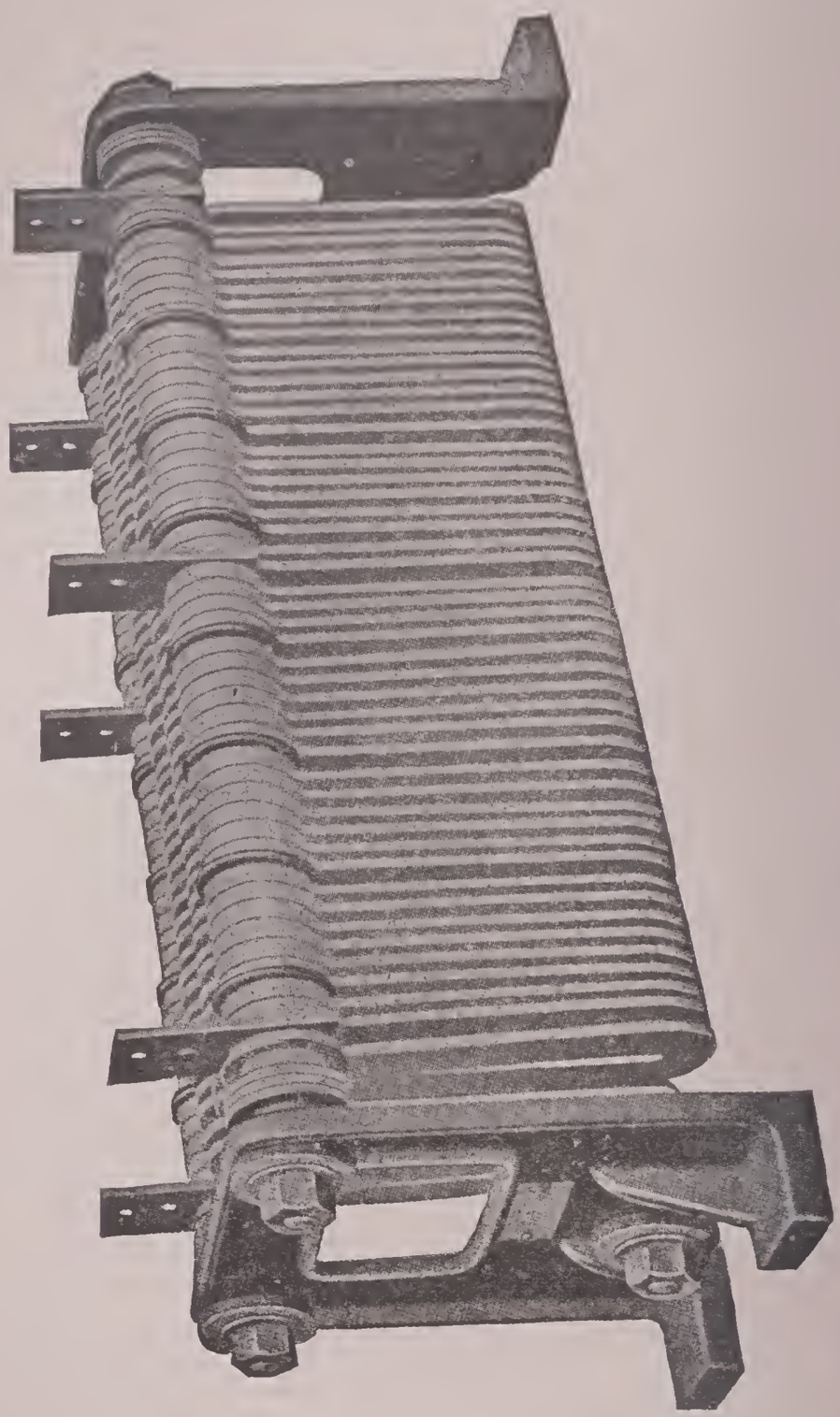


Fig. 506. Grid Resistance

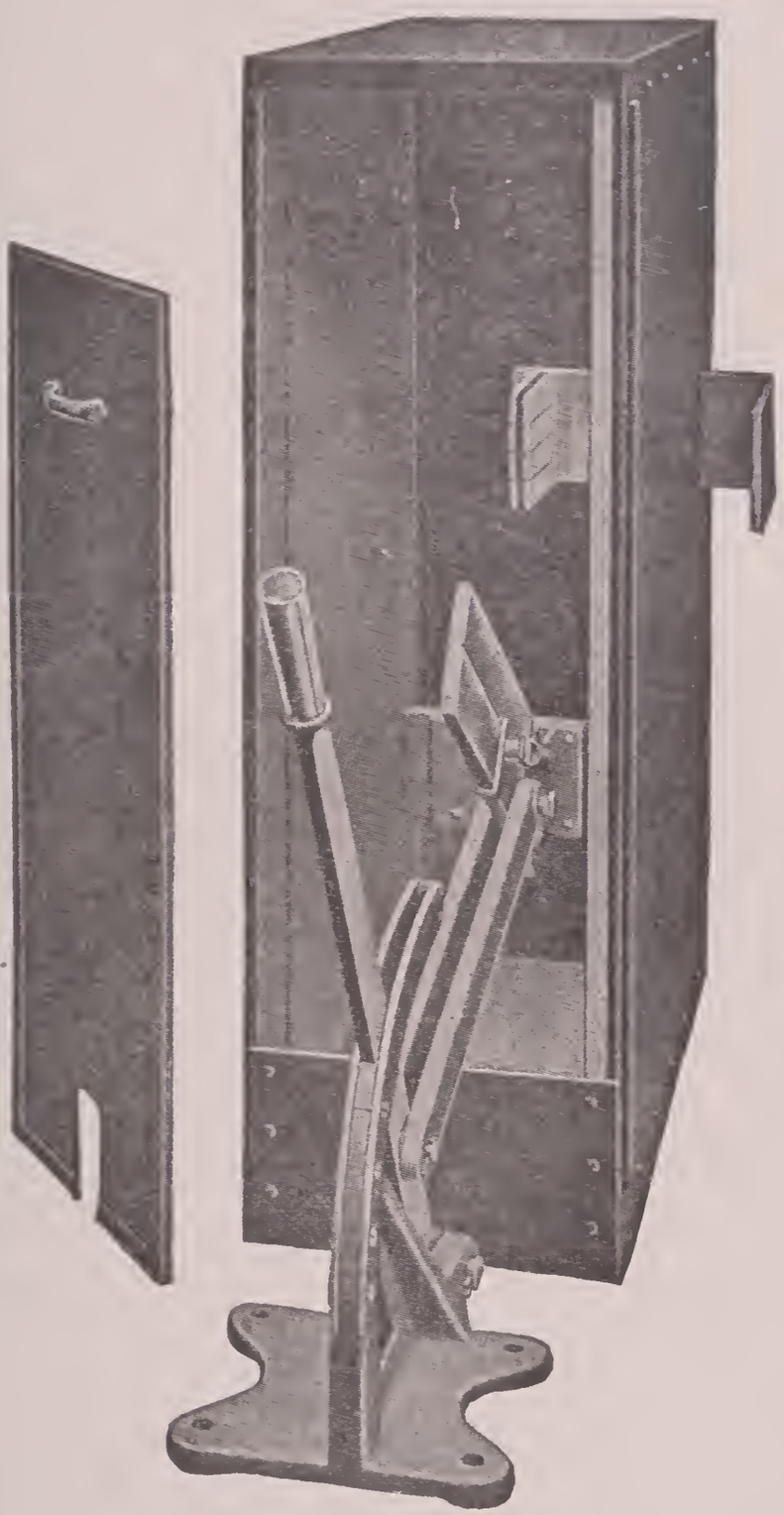


Fig. 507. Main Switch.

It should not be opened while current is on motors except in an emergency. It should, however, be opened before the individual motor fuses or contactors and reversers are examined.

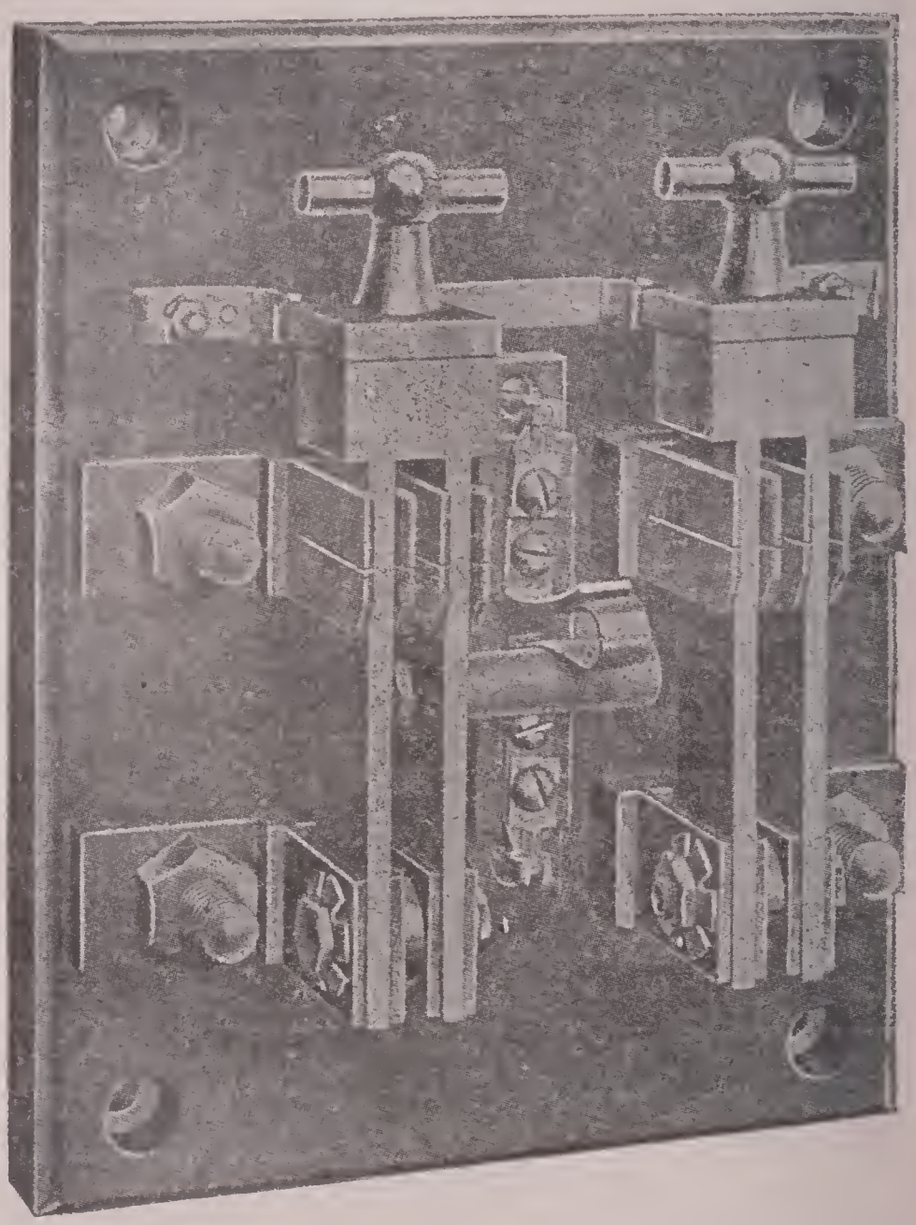


Fig. 508. Main Motor Cut-out Switches.

52. MAIN MOTOR CUT-OUT SWITCHES (Fig. 508) are for the purpose of cutting out the individual motors in case of any ground or defect in a motor which

renders it inoperative. There are four of these cut-out switches, one for each motor, and they are located on the sides of the cab, the switches for No. 1 and No. 2 motors being just over the No. 1 reverser and for No. 3 and No. 4 motors over the No. 2 reverser. The number of the motor to which it is connected is marked on each switch. Each switch also has a small auxiliary control cut-out switch which opens and closes with the larger switch for operating the circuit of the series contactor

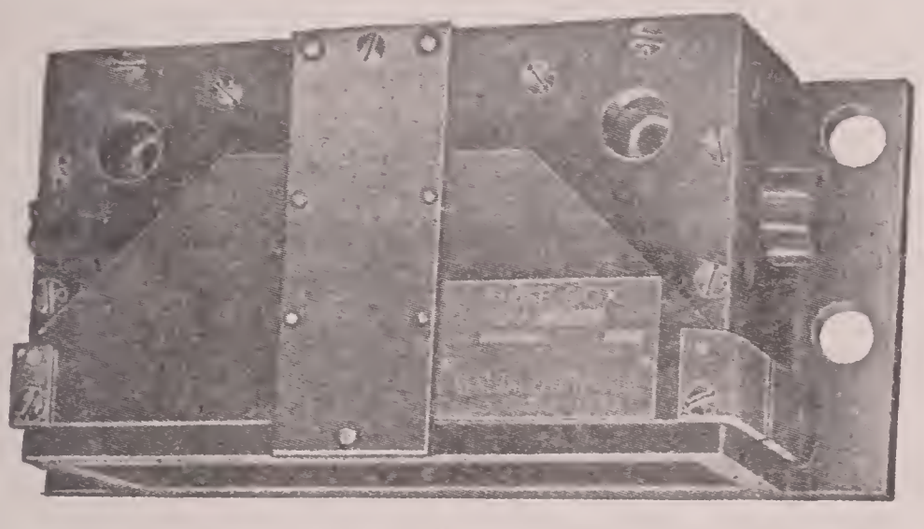


Fig. 509. Motor Fuse Box.

coils. These switches are normally kept closed, except in case of individual motor trouble. It should be seen that they are well closed, so that the small auxiliary switches make good contact. When one of these switches is opened on account of motor trouble, the locomotive will not move until controller handle reaches the eleventh notch.

53. MOTOR FUSE BOX (Fig. 509) (see paragraph 12, Suburban Cars, for general description of this type of fuse box). There are four of these fuse boxes,

each motor having its individual fuse. These boxes are located one over each third-rail shoe, just above the shoe fuse boxes. A copper ribbon fuse of 800 ampere rating is used in these boxes. Each box has marked on it the number of the motor whose circuit it protects.

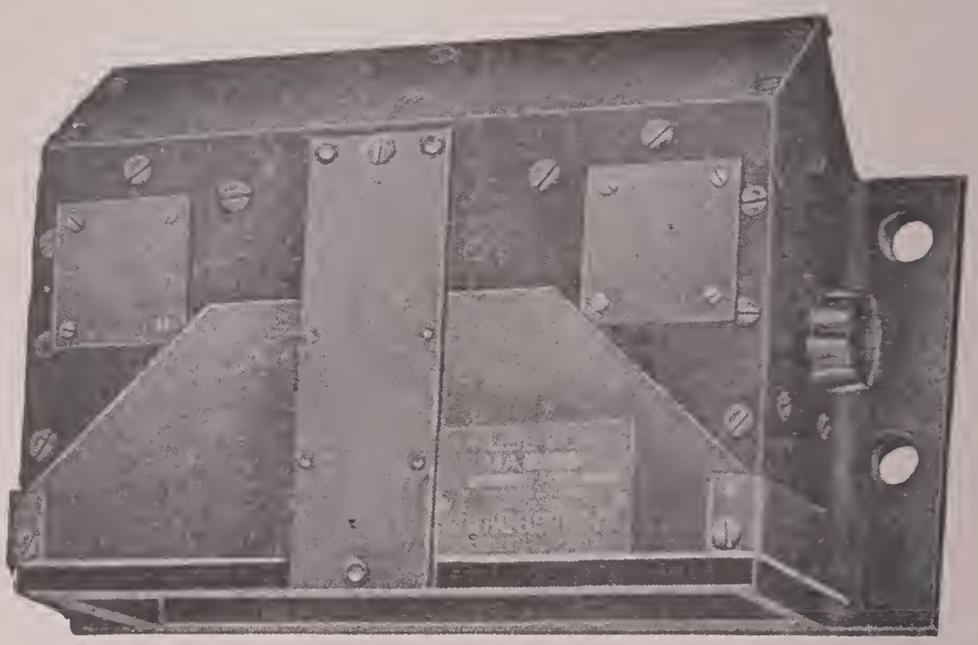


Fig. 510. Third Rail Shoe Fuse Box.

54. THIRD-RAIL SHOE FUSE BOXES (Fig. 510) are similar to the motor fuse boxes, but somewhat larger. There are two of these arranged in multiple for each pair of third-rail shoes and are mounted on brackets just above their shoes. Copper ribbon fuse of 1,600 ampere rating is used in each of these boxes.

55. OVERHEAD SHOE FUSE BOXES are practically the same as those for third rail shoe, but are mounted on the roof, two in multiple near each other. A copper ribbon fuse of 1,600 ampere rating is used here also.

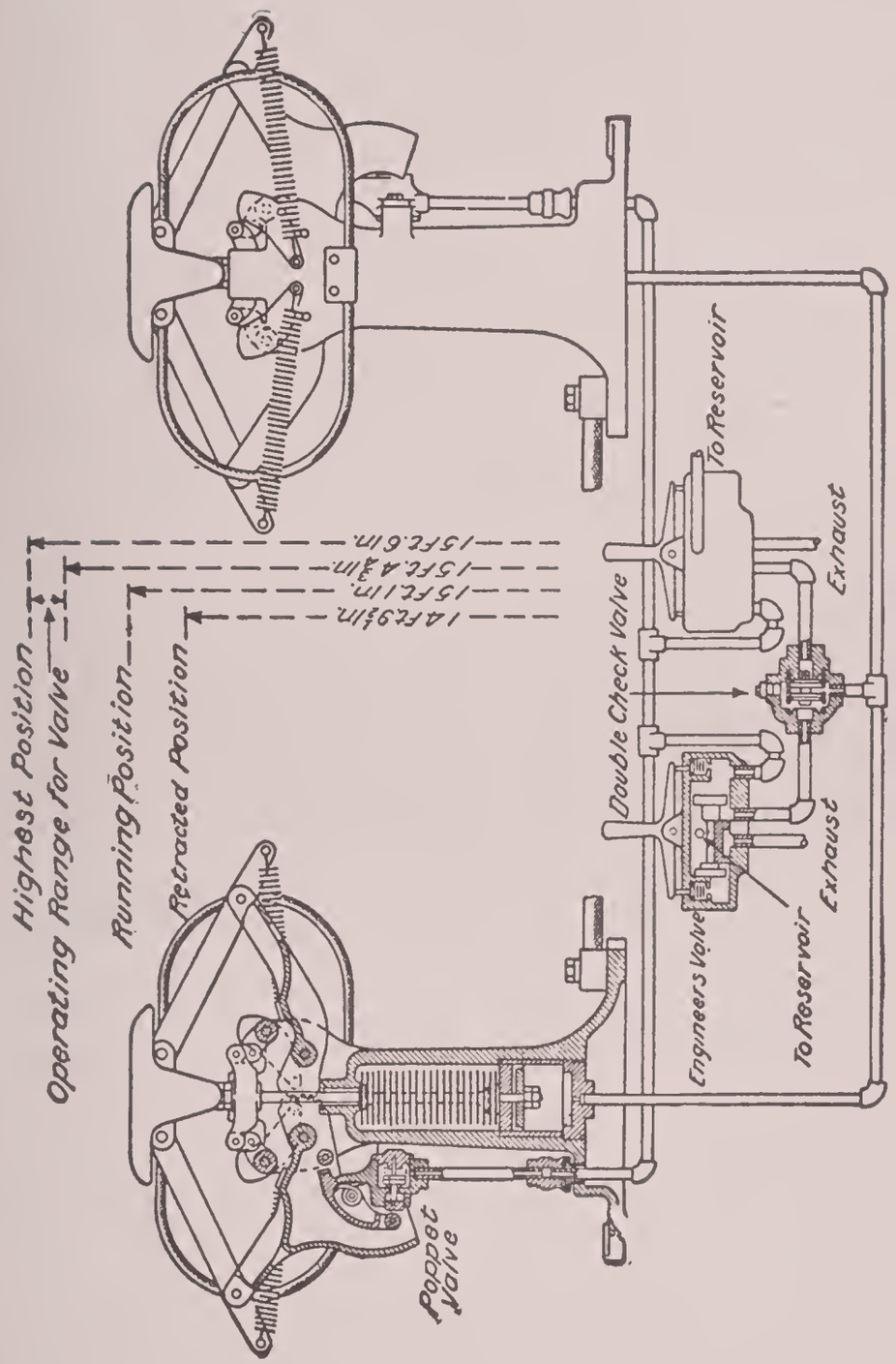


Fig. 511. Overhead Contact Device.

56. THIRD-RAIL CONTACT SHOES.—These shoes are of the "Slipper" spring actuated under-running type. The shoe bracket is mounted on a wooden insulating beam. There are two shoes in multiple on each bracket. Fig. 470.

57. OVERHEAD CONTACT DEVICE (Fig. 511) is a pneumatically operated shoe. There is a valve near each master controller in the cab, by means of which the

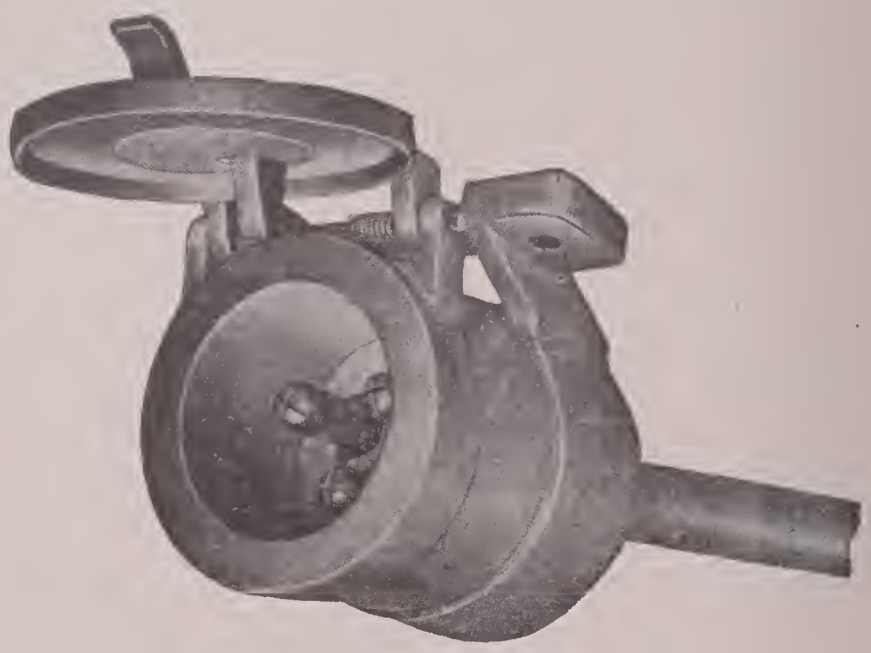


Fig. 512. Bus Line Coupler Socket.

shoe may be raised or lowered. When air is applied the shoe is lifted so as to make contact with the overhead rail. When air is released the shoe drops; also if the shoe runs off the rail it is tripped automatically and drops. Moving handle forward operates a pilot valve, by means of which a slide valve is thrown to admit air from reservoir to cylinder of contact shoe device. Pulling handle back operates another pilot valve and the slide valve is

Fig. 513. Bus Line Coupler or Jumper.

thrown over to connect air chamber of contact device to exhaust. The handle will spring back to the middle position from either direction. There are two of these overhead contact shoes, which are controlled in common by either valve in the cab. They are mounted on wooden insulating blocks. It is very important that these shoes should not be raised when they will come in contact with overhead obstructions.

58. THE BUS LINE COUPLER SOCKET (Fig. 512) has three split plug contacts, which are connected together for obtaining sufficient carrying capacity. (See paragraph 14, Suburban Cars, for general description.)

59. THE BUS LINE COUPLER OR JUMPER (Fig. 513). (See paragraph 15, Suburban Cars, for general description.)

C.—Master Control.

60. THE MASTER CONTROL APPARATUS comprises the following for each locomotive:

Two master controllers.
One main master controller switch.
Two overhead master controller switches.
One negative control switch.
Train cable.
Four train cable coupler sockets.
One train cable coupler or jumper.
One train cable connection box.
One train cable cut-out switch, combining also a second train cable connection box.
One current limit relay.
Control fuses.

61. THE MASTER CONTROLLER (Fig. 514) contains two movable cylinders, which are geared together, and stationary contacts for each mounted on insulation supports. The function of the controller in general is to supply current at the will of the engineer to the train cable for operating the reversers and contactors. The primary or slow-speed cylinder operates the contactors which produce motor combinations. The secondary of high speed cylinder operates those contactors which cut out the main motor resistance. The secondary cylinder is geared to primary at the ratio of about three to one. Geared to cylinders is a governor device, by means of which the movement of the controller handle and the cylinders is checked when current through the motors exceeds a certain amount. The controller has a separate reverse cylinder, and there is a separate handle for this. The reverse handle can be thrown only when the controller handle is in the "off" position. The "off" position of the controller handle is indicated and is the extreme forward position of handle. There are twenty-four operating notches and an "off" point on the controller dial ring. A latch on the handle engages the notches on the dial ring and has to be released in moving from notch to notch. The first ten operating notches are for series, the next seven for series parallel and the next seven for parallel operation of motors. The tenth notch is full series, the seventeenth full series parallel and the twenty-fourth full parallel position of motors, and at all other points motors will have resistance in circuit.

62. MAIN MASTER CONTROLLER SWITCH (Fig. 503) is located on side of passage way in "B" end compartment of cab and is used for admitting current to master controllers and should be closed to operate from

either master controller. The main purpose of this switch is to cut off line from the master controller fuse, which is located in this switch, in case the fuse has to be inspected or renewed. The fuse for this switch is 25 ampere capacity.

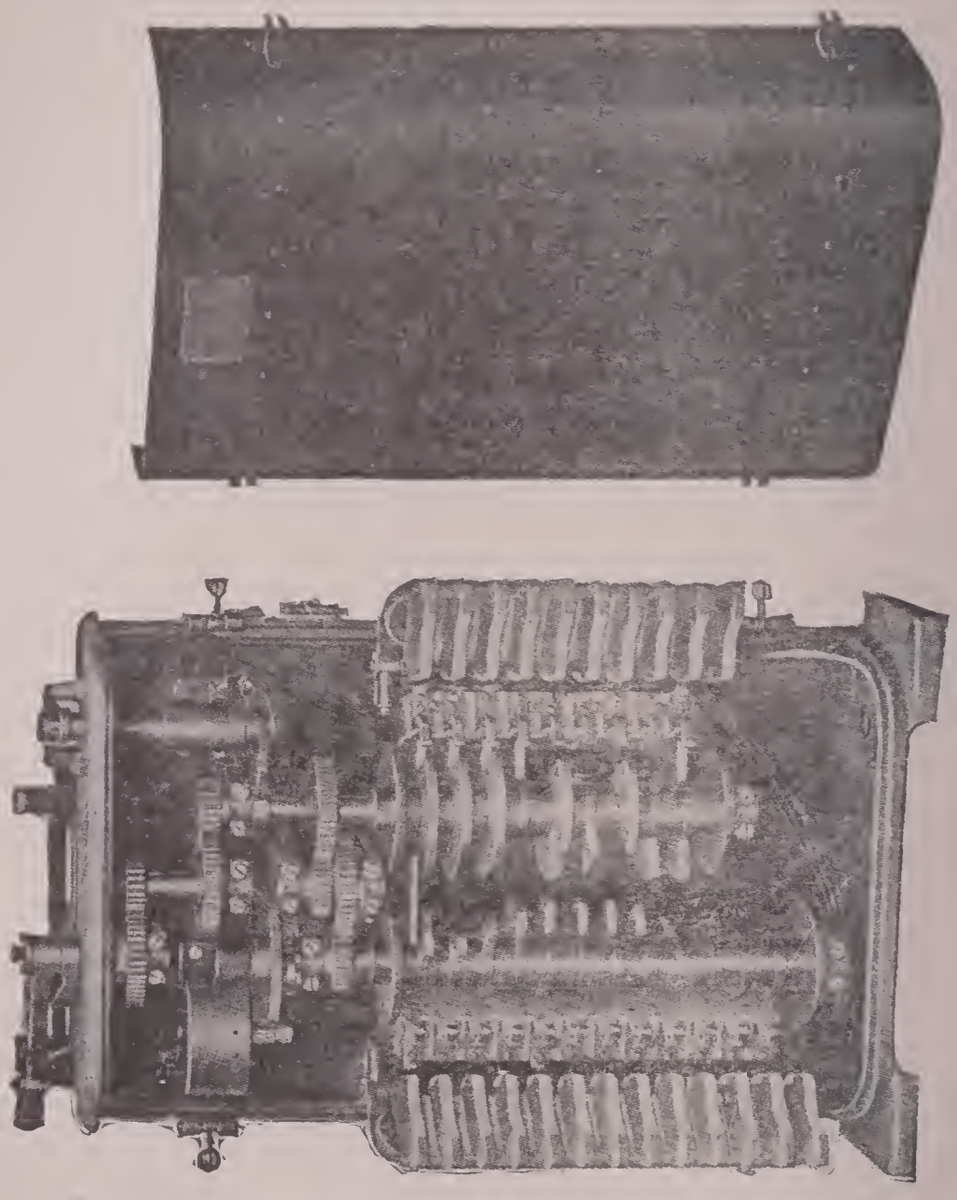


Fig. 514. Master Controller.

63. THE OVERHEAD MASTER CONTROLLER SWITCHES (Fig. 494) are located one over each master controller and are used for admitting or cutting off cur-

rent from the controller over which it is located. THE NEGATIVE CONTROL SWITCH (Fig. 494) is located on the side of the passage way of the "A" end.

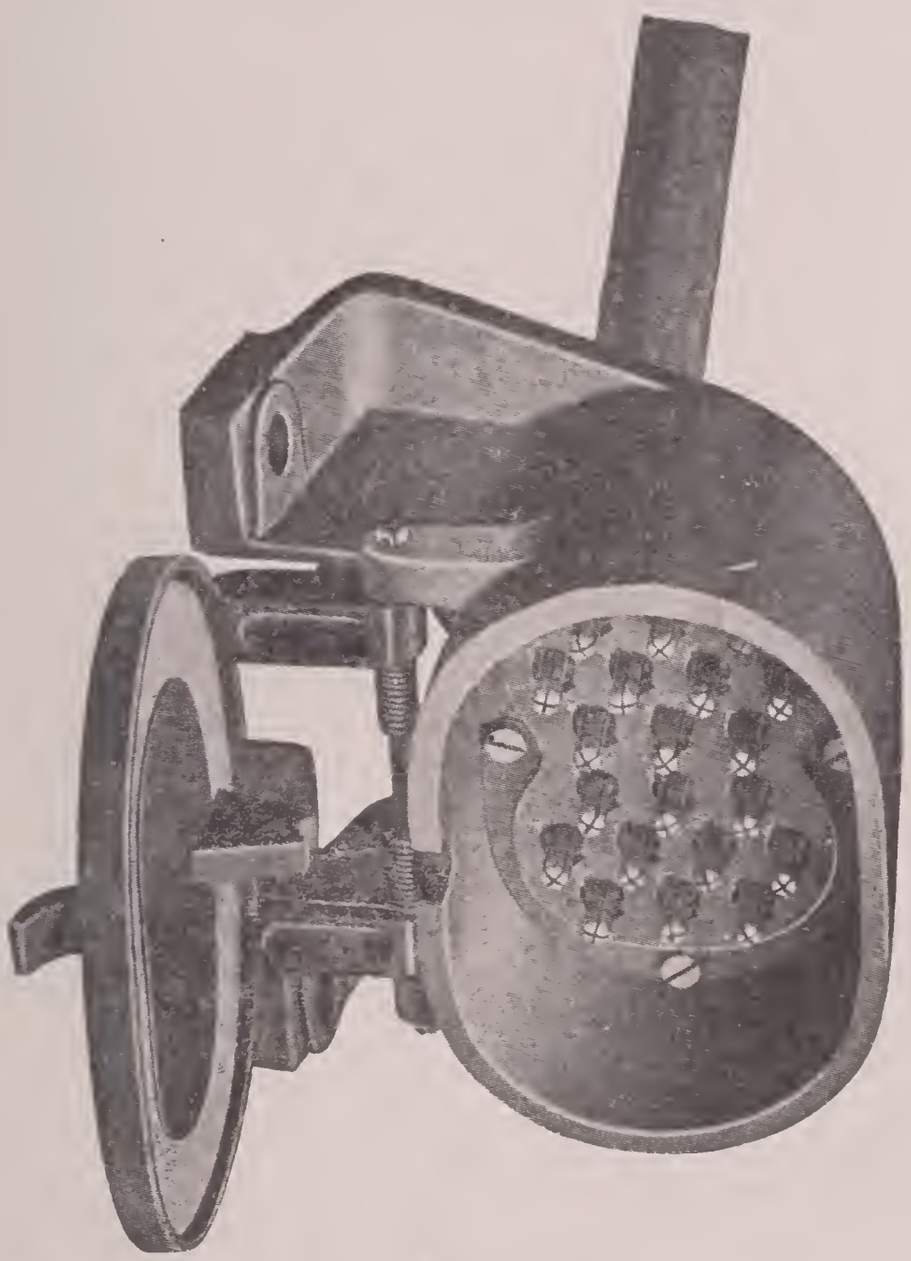


Fig. 515. Train Cable Coupler Socket.

Opening this switch cuts off ground from the reverser and contactor coils. It must be kept closed for operation. Ordinarily it need not be touched.

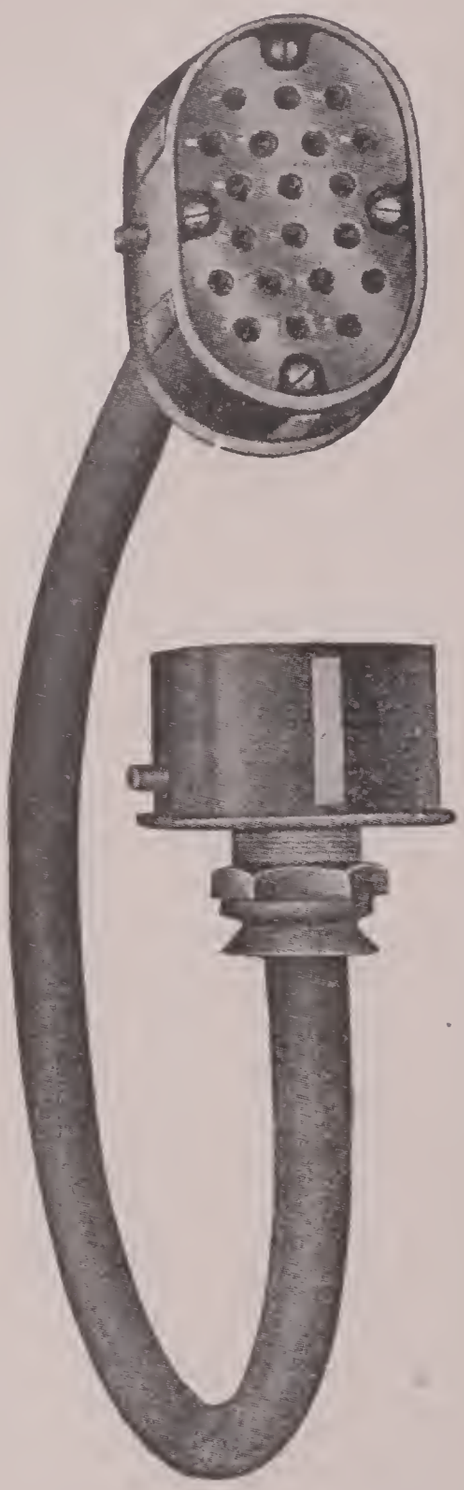


Fig. 516. Train Cable Coupler Plug.

64. The TRAIN CABLE is composed of twenty conductors, which are attached to numbered plugs in the coupler sockets, and there are branches from seventeen of these wires extending to the master controller. These seventeen wires are used as follows:

No. 1.—For operating series contactors.

Nos. 2 and 5.—For operating series-parallel contactors.

No. 3.—For operating bridge contactors.

Nos. 2 and 4.—For operating parallel contactors.

Nos. 6, 7, 10, 11, 12, 13, 14, 15 and 16.—For operating resistance contactors.

No. 18.—For operating controller governor.

No. 0.—For operating reverser one direction.

No. 8.—For operating reverser other direction.

Nos. 19 and 20 are used for operating the sander device.

No. 17 is an extra wire.

65. THE TRAIN CABLE COUPLER SOCKET (Fig. 515) has twenty contact studs otherwise the general description, paragraph 23, Suburban Cars, will apply to this coupler socket.

66. THE TRAIN CABLE COUPLER PLUG (Fig. 516) has twenty contacts to agree with coupler socket. (See general description, paragraph 24, Suburban Cars.)

67. TRAIN CABLE CONNECTION BOXES are used for making connections from master controller and coupler sockets to the train cable. One of these connection boxes (Fig. 517) is combined with the twenty-point cut-out switch. This is mounted on the back of the master controller on the "A" end of the cab. This is the No. 2 connection box. The plain connection box (Fig. 518) is

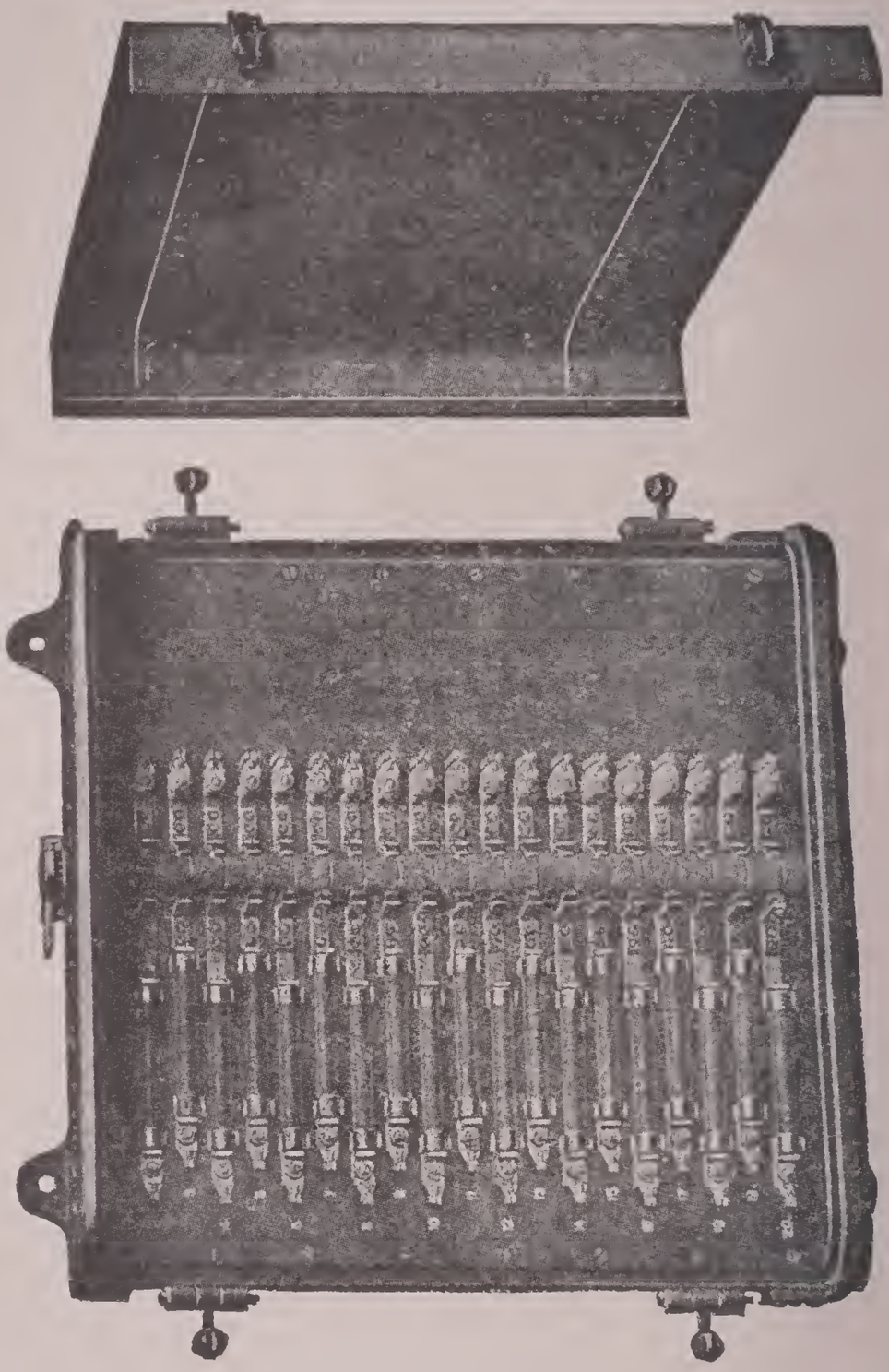


Fig. 517. Train Cable Connection Box.

mounted on the back of the controller at "B" end of the cab. No. 0 wire from No. 1 box connects to No. 8 wire in No. 2 box, and No. 8 from No. 1 box connects with No. 0 in No. 2 box. All other wires connect number to number. One of the wires in the outside layer is covered

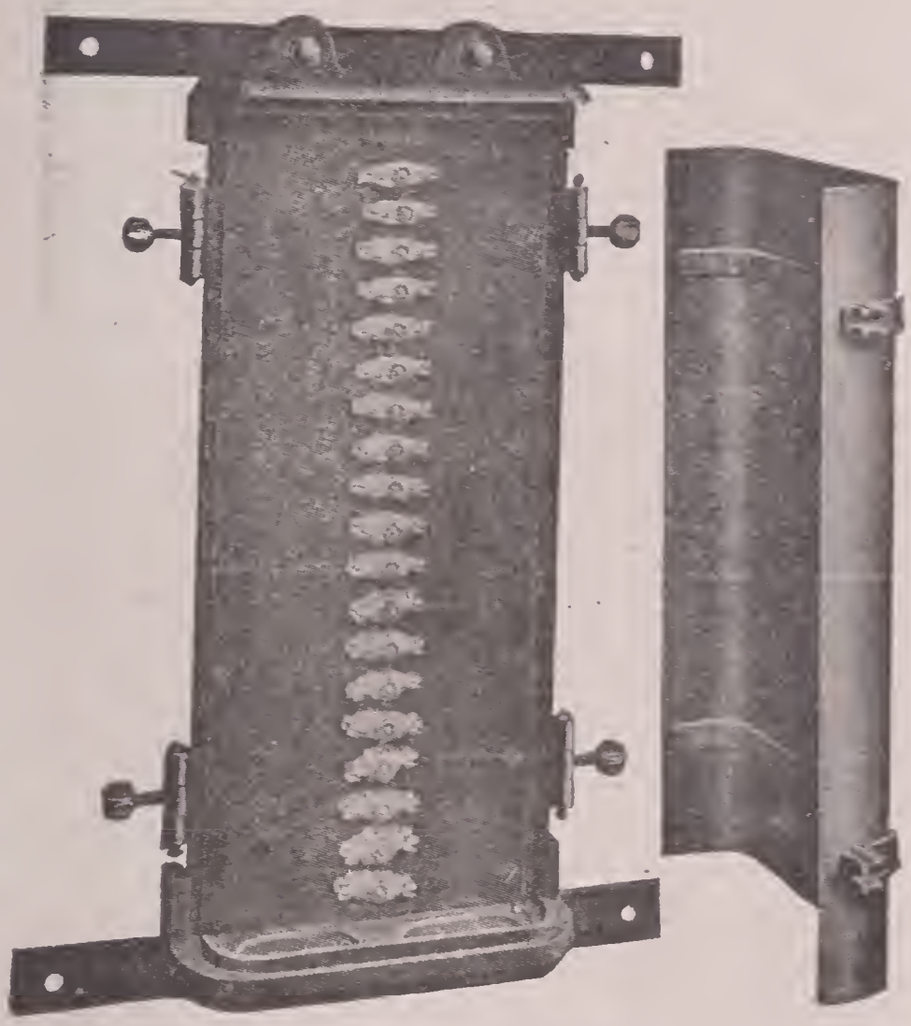


Fig. 518. Plain Connection Box.

with green braid. This is No. 1 wire, the other wires of this layer being numbered in the counterclock-wise direction from this. The red covered wire in the inner layer is No. 14, the others being numbered counterclock-wise direction.

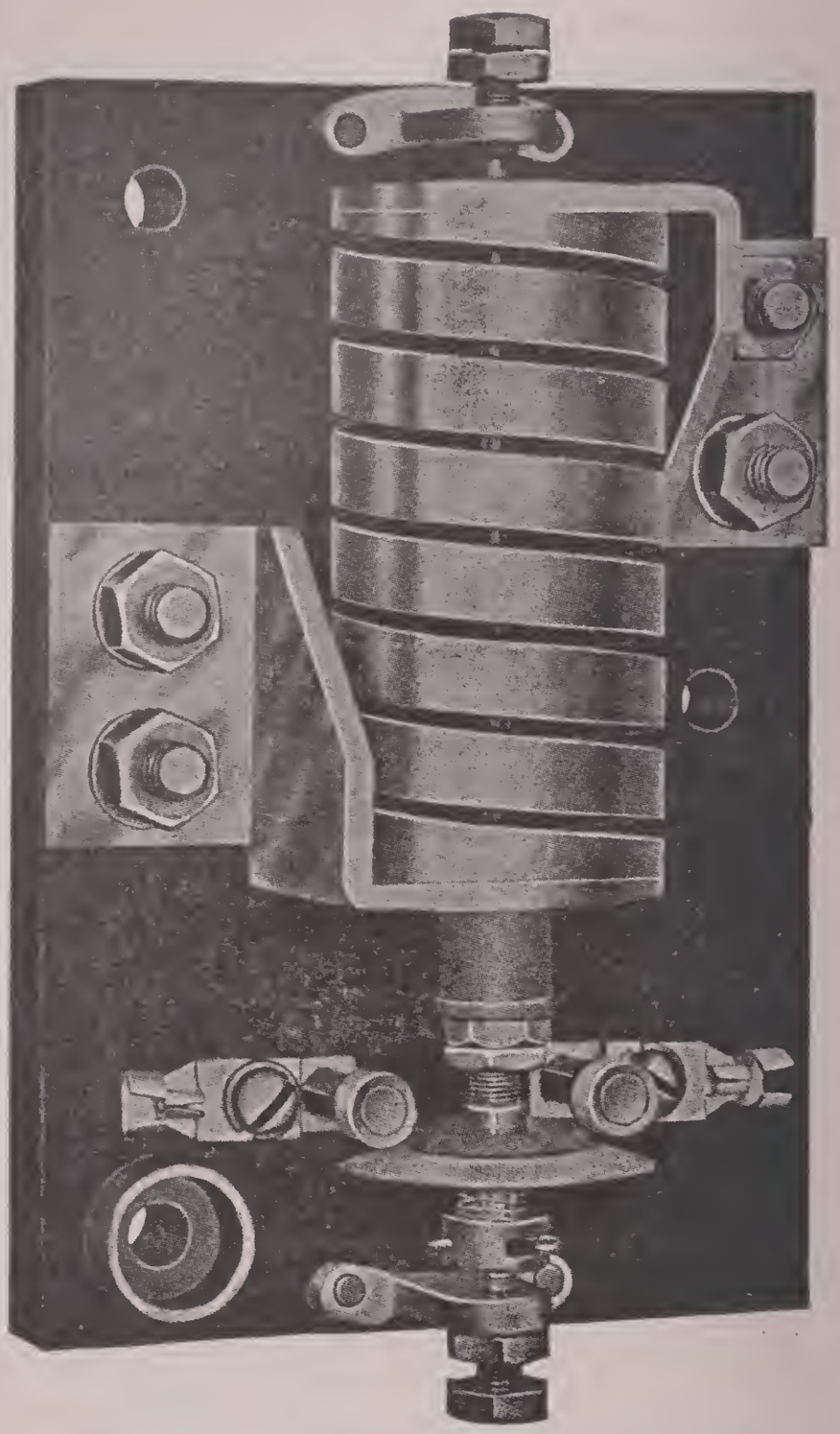


Fig. 519. Current Limit Relay for Locomotive.

68. THE CURRENT LIMIT RELAY (Fig. 519) is located just above the No. 1 reverser and is provided for the purpose of checking a too rapid movement of the controller handle in getting the train up to speed. The relay coil is connected in series with No. 2 motor circuit. If the current through the motor exceeds a certain amount, the plunger of relay picks up and closes a set of contacts which supplies current to the controller governor. The controller handle is thus held from being moved on and cannot be moved another notch until the current through the motor falls to a certain amount.

69. THE CONTROL CUT-OUT SWITCH (Fig. 517) has already been referred to under the subject of CONNECTION BOXES. The connection studs of this box also serve the purpose of the No. 2 connection box. This cut-out switch serves the purpose of disconnecting the control circuits of contactors and reversers on a locomotive from the train line. The cut-out switch has twenty sets of contacts which are connected or disconnected accordingly as the handle is full around to the left or to the right.

70. CONTROL FUSES (Fig. 517) are mounted on the same insulation back as the cut-out switch and are contained in the same box. The fuses numbered from the top protect the following circuits:

No. 1—Series contactor coils.

Nos. 2 and 5—Series parallel contactor coils.

Nos. 2 and 4—Parallel contactor coils.

No. 3—Bridge contactor coils.

Nos. 8 and 9—The reverser operating coils.

Nos. 6, 7, 10, 11, 12, 13, 14, 15 and 16—The resistance contactor coils, respectively, one fuse protecting the contactor coils for each resistance step of controller.

No. 17 is not required but is extra.
No. 18—Controller governor circuit.
Nos. 19 and 20—Sander circuits.

D.—Air-Compressor Control.

71. The air-compressor control comprises the following pieces of apparatus:

A pump motor switch.
A pump governor.
A pump motor circuit contactor.

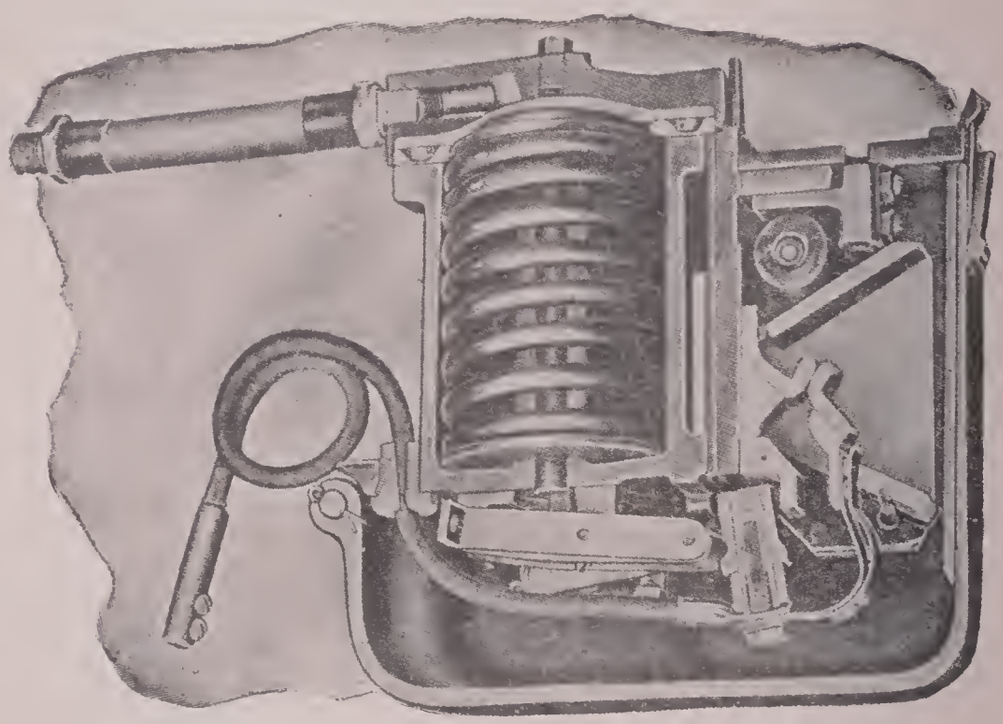


Fig. 520. Sectional View Air Pump Governor.

72. PUMP MOTOR SWITCH (Fig. 503) is located on side of passage "A" end compartment. This switch is for the purpose of opening the pump motor circuit when locomotive is not in service. This switch contains a 40-ampere fuse, which protects the pump motor circuit.

73. PUMP GOVERNOR (Fig. 520) is located in "A" compartment on side opposite No. 2 reverser. The

governor is of the diaphragm type of construction, the movement of the diaphragm, as air pressure falls or rises, operating a lever mechanism which serves to give a quick make and break to a small switch of the contactor type. This switch does not close the pump motor circuit itself, but closes the circuit through the PUMP MOTOR CIRCUIT CONTACTOR, which has higher current capacity on its contacts than the governor. This contactor is located to the left of the governor. When the air pressure in the reservoir falls to 130 pounds, the governor closes its contacts, thereby energizing the contactor coil, which in turn closes its contacts; the pump motor circuit being thus completed the pump starts. When the air pressure reaches 140 pounds the governor opens the circuit of the contactor coil, which in turn opens and breaks the pump motor circuit and the pump stops.

But the governor and the contactor have strong magnetic blow-outs at their contacts, sufficient to handle any current which they may take in this service.

E.—Track Sander Control.

74. The track sander control comprises the following pieces of apparatus:

One main sander switch.

Two sander operating switches.

Two electro-pneumatic valves.

75. MAIN SANDER SWITCH (Fig. 503) located in the "A" end compartment of cab, is for the purpose of admitting or cutting off current from the sander operating switches. This switch contains a 10-ampere fuse. The switch should be opened on inspecting fuse. This switch has plate marked "Sander."

76. SANDER OPERATING SWITCHES (Fig. 521) are located one on side of cab near each master controller. These are double-throw switches and are marked "Sand Forward," "Sand Reverse." Moving

Fig. 521. Sander Operating Switch.

handle to the "Forward" position energizes the valve which will apply sand to rail for forward direction. "Reverse" position of handle will apply sand for the reverse direction.

77. ELECTRO-PNEUMATIC VALVES (Fig. 522) are located one in each end compartment. One valve operates a sander for one direction of movement, the

other valve operates a sander for the other direction, only one valve being operated at a time. The valve is operated by a magnet which is energized by current applied in the sander operating switch.

F.—Train Operation—General.

78. Before attempting to start the locomotive of train the motorman should first close the pump switch, then close the main switch and see that the main control switch and all the cut-out switches are closed. After the reservoir and train line are charged the overhead control switch over the controller from which locomotive is to be operated should be closed and the reverser handle thrown in the direction of desired movement of locomotive. The motorman may then proceed on the signal.

After releasing the latch on controller handle pull controller handle to the first notch, then to the second notch, and so on, until the desired speed is attained. For coupling, with the locomotive, light, the first or second notches will ordinarily be sufficient. If it is desired to get up to speed as soon as possible the handle may be moved around notch by notch, allowing the latch to take each notch until the last notch is reached.

If the motorman feels at any point, the further movement of the controller checked, he should not exert undue pressure on handle—no more than is ordinarily required to move the handle from one notch to the next. Whenever the current through the motors is higher than a certain amount the automatic governor acts and stops the further movement of handle. When the current falls to a certain amount the governor releases controller cylin-

ders and another notch may be taken, and so on. Every notch on the controller should invariably be taken by latch in moving controller on, whether in accelerating or in throwing controller on with motors already up to

Fig. 522. Electro-Pneumatic Sanding Valve.

speed. In throwing off, the notches need not be observed.

The "off" notch of the controller may be called the zero notch. The first closed position of the controller is the first notch and so on, the tenth notch being the full series

position, the seventeenth notch the full series parallel position and the twenty-fourth notch the full parallel position. The tenth, seventeenth and twenty-fourth notches may then be called running points. The intermediate points are resistance points and should ordinarily be used only for accelerating or switching. The tenth notch gives one-quarter speed, the seventeenth notch one-half speed and the twenty-fourth notch full speed. The transition from the tenth to the eleventh notches and from the seventeenth to the eighteenth should be made promptly, without pause between.

When the controller is on any notch the current passes from the master controller switch through the master controller of the train cable of one or two locomotives and thence to the reverser operating coils and the contactor coils, which correspond to the given notch, as shown in the following table. This table give the numbers of the contactors which are closed on each step of the master controller. The numbers that are underscored indicate the contactors which are closed on that step in addition to previous ones.

Controller Steps.		Contactors Closed.
	1	1-2-4-19-22-25-33-41-42
	2	1-2-4-<u>18</u>-19-22-25-33-41-42
	3	1-2-4-18-19-22-25-33-<u>39</u>-41-42
	4	1-2-4-18-19-22-25-<u>31</u>-33-39-41-42
Series.....	5	1-2-4-<u>5</u>-<u>13</u>-18-19-22-25-<u>26</u>-31-33-<u>34</u>-39-41-42
	6	1-2-4-5-<u>6</u>-13-<u>14</u>-18-19-22-25-26-<u>27</u>-31-33-34-<u>35</u>-39-41-42

7	1-2-4-6-7-14-15-18-19-22-25-27-28-31-33-35-36-39-41-42
8	1-2-4-7-8-15-16-18-19-22-25-28-29-31-33-36-37-39-41-42
9	1-2-4-8-9-16-17-18-19-22-25-29-30-31-33-37-38-39-41-42
10	1-2-4-9-10-17-18-19-22-25-30-31-33-38-39-41-42
First Bridge.	1-2-4-11-19-25-32-33-41-42
11	1-2-4-11-18-19-21-23-25-32-33-39-41-42
Series Parallel..12	1-2-4-5-11-13-18-19-21-23-25-26-32-33-34-39-41-42
Series Parallel..13	1-2-4-5-6-11-13-14-18-19-21-23-25-26-27-32-33-34-35-39-41-42
14	1-2-4-6-7-11-14-15-18-19-21-23-25-27-28-32-33-35-36-39-41-42
15	1-2-4-7-8-11-15-16-18-19-21-23-25-28-29-32-33-36-37-39-41-42
16	1-2-4-8-9-11-16-17-18-19-21-23-25-29-30-32-33-37-38-39-41-42
17	1-2-4-9-10-11-12-17-18-19-21-23-25-30-31-32-33-38-39-40-41-42
Second Bridge	1-2-4-12-19-21-23-25-33-40-41-42
18	1-3-4-19-20-21-23-24-25-33-41-43

Parallel....	19	1-3-4-5-13-19-20-21-23-24-25-26-33-34-41-43
	20	1-3-4-5-6-13-14-19-20-21-23-24-25-26-27-33-34-35-41-43
	21	1-3-4-6-7-14-15-19-20-21-23-24-25-27-28-33-35-36-41-43
	22	1-3-4-7-8-15-16-19-20-21-23-24-25-28-29-33-36-37-41-43
	23	1-3-4-8-9-16-17-19-20-21-23-24-25-29-30-33-37-38-41-43
Parallel....	24	1-3-4-9-10-17-18-19-20-21-23-24-25-30-31-33-38-39-41-43

If the reversers are not already thrown to the position corresponding with the position of the reverser handle, when the controller is thrown to the first notch, current will first pass through the proper operating coil to ground. After the reversers have reached the correct position interlocking contacts on each reverser cut off current to ground and establish a circuit through three contactor coils. Moving the reverse handle does not operate the reversers, but simply arranges the contacts, so that when the controller is turned to the first position reversers will be thrown in the proper direction. The operating coil for one direction on one reverser is in multiple with the corresponding coil on the other reverser, these two coils being controlled by one wire from the master controller and protected by one fuse.

On the first notch the main or motor current flows from the third-rail shoes or from the overhead shoes through the shoe fuses to the main switch, then through

the No. 1 motor fuse, through the reverser and No. 1 motor, through a set of rheostats to reverser and No. 2 motor, then through the other reverser and No. 3 motor through a set of rheostats, then through another set of rheostats to reverser and No. 4 motor and then to ground. The four motors are here all in series, with all the resistance in circuit; and the locomotive, if light, may start, or if coupled to a train may simply take up drawbar slack. Each of the next three steps cuts out one complete set of motor resistance, and on succeeding steps, until full series is reached, the remaining set is cut out in six more steps. After full series, between the tenth and eleventh notches, bridge connections are established, and then on the eleventh notch motors are thrown in series parallel relation. Resistance is cut out in six steps to full series parallel, the seventeenth notch. Bridge connections are then established and motors are then thrown all in parallel, the resistance being cut out again in six steps. When motors are in parallel each is protected by its own fuse.

When it is necessary to reverse the direction of train movement, leaving controller handle in the off position, throw the reverser handle in the opposite direction and then move controller handle on in the same way. The reverser handle is to be thrown in the direction corresponding to direction of movement required. The motors should not be reversed while the locomotive is moving, except in case of emergency and then if speed is more than a few miles per hour the wheels would probably slip. If it is necessary to reverse while moving, do not throw controller handle beyond the first notch, if all the motors are cut in, or beyond the eleventh notch if one motor is cut out.

When operating on an overhead rail section the overhead contact shoe will be tripped and will drop on leaving this section. The motorman should, however, as an extra precaution, throw the valve handle back. Either for raising or lowering the overhead shoe it is necessary to hold handle in position only long enough for the shoe to start movement.

To sand the rails the SANDER OPERATING SWITCH should be moved over in the direction of movement of the locomotive. To stop the sand the handle of this switch must be brought back to the middle position.

The control cut-out switch, if open, disconnects the operating parts of contactors and reversers on the locomotives from the train cable, but does not affect the operation of the other locomotive if two are connected together, although it is cut out on the locomotive whose master controller is being operated. The control connections for the reverser are so arranged that unless it is at the proper position current is cut off from contactors, so that motors on that locomotive will receive no current. In case of electrical trouble within the master controller train cable, couplers, or connections boxes, the single fuse in the master control switch will protect them. In case of local trouble on contactors or reversers the fuses in the cut-out switch will protect the circuit.

AIR-BRAKE EQUIPMENT ON MOTOR CARS.

A.—General.

The air brakes on the cars and locomotives in electric service are essentially the same as those on the other passenger equipment, except that the steam driven air pumps on the locomotives are replaced by electrically driven air compressors, one on each electric locomotive and each motor car, and the design of the air brakes is such that their release, as well as application, can be graduated.

The use of an air compressor and main reservoir on each motor car necessitates the use of an additional train pipe to connect all the main reservoirs together and to the motorman's brake valve. This extra train pipe is called the control pipe.

A safety valve is placed in the end of the main reservoir on each motor car to prevent overcharging the brake system in case the electric pump governor fails.

B.—Hints to Motormen.

In suburban service it is highly important not to block the road. Therefore, remember in case anything gets out of order that the first important thing is to get out of the way; learn carefully just what to do in order to make the proper move quickly; for example:

1. In case of a burst hose, if it be the control pipe hose, the cut-out cock on both sides of it should be closed; but if it should be the brake pipe hose, then it is neces-

sary to close the cut-out cock ahead of the brake and the double cut-out cocks on each of the cars back of it; then open, and leave open, the auxiliary reservoir bleed cocks on all of the cars that are cut out. In a case of this kind some one would be designated and prepared to operate the hand brakes on the cars that are cut out in case a car coupling should break and cause the train to separate.

2. In case of inability to release a brake, caused, for instance, by the emergency valve remaining unseated after an emergency application, close double cut-out cock and open and leave open, bleed cock of auxiliary reservoir on this car and proceed.

3. In case of brake sticking after service application, make about a ten-pound reduction and place the handle of the brake valve in release position. This will usually release the brake. If not, or further trouble is had with this brake, do as recommended in preceding case 2.

It will be seen by these examples that by a knowledge of the operation of the air-brake the motormen and trainmen can formulate rules for themselves that, in case of trouble, will enable them to get out of the way with little or no delay.

To gain time adapt the brake-pipe reduction, or application of brakes, to speed. For example, for high speed made a full application and graduate off when a short distance from the stop. To handle train smoothly make the application heavy and soon enough, so that if held on the train would stop a car length or so short of the mark. Then as the stop or mark is approached graduate the pressure out of the brake cylinder so that little remains when stop is made. If on a level, complete the release; if on a grade, hold until the signal to start is given, then release. As the pressure has been graduated down so

that little remains in the cylinder, it will be seen that the start can be made promptly.

As the automatic brake is applied by the reduction of the brake-pipe pressure, no matter how produced, it is plain that leaks will produce results not intended or desired by the motorman, and sometimes interfere with the accuracy and smoothness of the stop. Therefore, they should be kept down and reported as surely and promptly as any other defect. Motormen should observe as carefully as possible the action of the governor, feed valve and gauges; that is, their adjustment, etc., as much better operation can be obtained if all are approximately uniform.

One of the things that the motorman should learn carefully regarding the automatic brake is, that after a certain reduction of pressure in the brake pipe, say eighteen to twenty pounds, the auxiliary reservoir and brake cylinder have equalized. Therefore, no greater braking power can be obtained, and to further reduce the brake pipe pressure wastes a great amount of air which must be restored to the brake pipe before a release can be made, and interfere with that release to such an extent that a rough stop is usually the result.

Properly handled this brake possesses all the flexibility of the straight-air brake, while the safety and reliability of the automatic brake has been greatly increased. Therefore the motorman should endeavor to understand its principles, so that he can handle the brake so as to obtain its maximum efficiency with credit to himself and comfort to the passengers.

AIR COMPRESSOR ON ELECTRIC LOCOMOTIVES.

A.—General.

The CP-19-B air compressor consists of a duplex, single-acting, vertical air pump, located between and directly connected to two 8-pole series, direct-current motors. It has a piston displacement of 75 cubic feet per minute, when operating on 600 volts, and against a tank pressure of 130 pounds per square inch. Fig. 523.

The compressor frame is so shaped as to form a large oil chamber for the cranks and connecting rods. It is provided with a pedestal-like base, arranged to support the machine, and bolted to the floor of the locomotive cab. To this frame the motor frames are bolted, one to each end. The vertical cylinders are bolted to the top, and large oil-tight doors are provided, one on each side, for admission to the cranks and bearings.

The pistons are provided with single rings of the three-section type. Each cylinder is provided with independent intake and exhaust valves. These valves are of the tubular type, operating in a vertical position on the tops of the cylinders.

The intake for the air is provided with a copper screen, located in a box, which can be easily removed and cleaned when necessary.

The crank chamber is provided with baffle plates, above and below, for the purpose of preventing too much splashing of oil into the cylinders.

The armatures are fastened directly to the crank shaft. Each end of the shaft is tapered and supplied with key and clamping nut, for the purpose of securing the armatures and providing means for their removal.

The pole pieces are made of soft iron sheets, securely riveted together and bolted to finished surfaces on the inside of the motor frame.

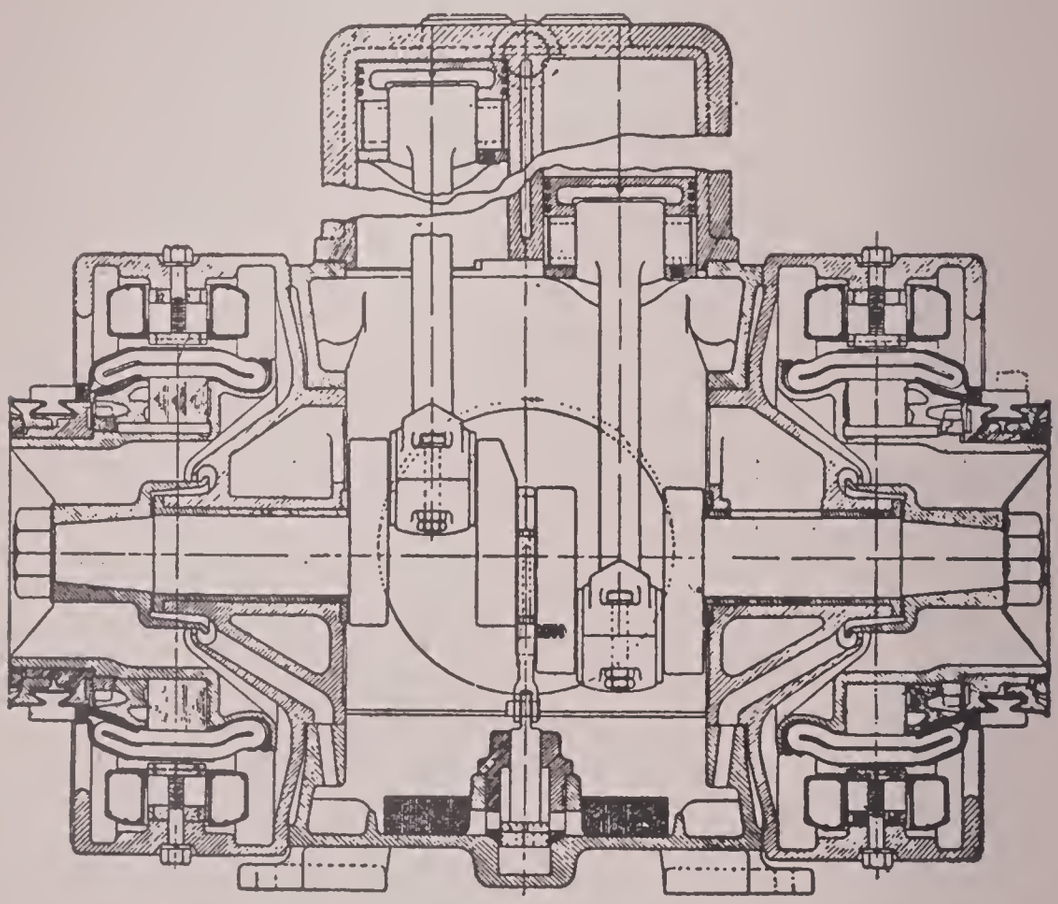


Fig. 523.

The brush holders are supported on insulated radial studs held by clamps bolted to the ends of the motor frames in such a manner as to permit adjustment to accommodate the wear of the commutator. The outside end of each motor is provided with a large ventilated

shield, semi-closing the machine, and affording protection for the armatures and brush holders.

The machine has a total of six bearings, consisting of one crank bearing, and one wrist bearing for each of the two connecting rods, and two main bearings. The main bearings are located in the motor frames, one on each side of the crank portion of the driving shaft. All bearings are provided with removable bronze linings. The connecting rods are split on the diameter of the crank pin, and the crank bearings are held in place by caps bolted to the lower ends of the connecting rods. The main bearings are oiled from waste packed pockets formed in the motor frame castings. The crank bearings are lubricated by oil splashed by the connecting rods. The wrist bearings are lubricated by oil supplied to them through pipes connected to pumping devices located on the lower ends of the connecting rods so as to dip into oil in the bottom of the crank chamber.

B.—Operation.

The CP-19-B air compressor is intended to operate on 600 volts, and for such operation the motors should always be connected in series.

The direction of rotation of the armatures should be such that the top side of the commutator travels toward the observer, when standing on the side of the compressor where the air intake is located, and the intake openings in the oiling devices should recede while sweeping through the oil.

Should it be necessary to remove an armature, take off the end shield and remove brush holders; then take off the armature nut. Before removing the nut, it will be

necessary to straighten out lock washer underneath the same. When the nut has been removed two bolts of proper length, with hooked ends, should be hooked behind two spokes of the armature spider diametrically opposite each other. The outside ends of these bolts should be threaded, and should pass through holes in a piece of iron, held against the armature shaft in such a manner that when tightened the armature will be loosened and pulled off.

When it becomes necessary to replace a lining for a main bearing it will be necessary to remove the armature and armature key. The lining can be then drawn out of the motor frame over the shaft by bolts screwed into tapped holes in the end of the lining.

As the commutator wears down it may become necessary to adjust the brush holders. The brush *holders* should be located about one-eighth of an inch from the commutator, and can be adjusted by loosening clamping bolt so the supporting stud can slide in the clamp.

In replacing brush holders which have been removed, care should be taken to move them over as far as possible in the direction opposite to the rotation of the commutator, so as to produce sparkless commutation.

If it should be observed that a compressor appreciably increases its speed, from causes other than increase in voltage, and seems not to be delivering the proper amount of air, attention should be given to the intake valves, as such a condition might be caused by valves sticking, or not properly seating due to accumulation of dirt. The valve in question should be taken out and thoroughly cleaned, care being taken not to leave particles of thread or lint sticking to it.

Should the intake valves fail to open with every stroke on the compressor, attention should be given to the exhaust valves. If the exhaust valves leak, or remain open for any reason, the cylinder will receive air from the reservoir, and will not give the intake valves an opportunity to open. When these valves are out care should be taken not to drop dirt into the cylinders, as the clearance between tops of cylinders and pistons is very small.

Valve trouble of any kind rarely happens with this type of valve, and can be caused only by accumulation of dirt. The operator will soon learn to know from the peculiar click of the valves whether or not they are working properly.

Should it become necessary to remove a piston or connecting rod, the cylinders must be taken off, then the crank caps removed from the connecting rods, upper baffle plate removed, and connecting rod and piston drawn upwards out of the compressor frame.

Oil should be maintained in the crank chamber to within about one-half inch of the centre portion of the lower baffle plate, and should never be allowed to become so low as not to permit the oiling device to properly dip into the same.

The frame of the machine is designed to catch oil splashed in the crank chamber and deliver it to the main bearings. However, the waste pockets around these main bearings should be examined from time to time to see that the waste is tight against the shaft, and is receiving the proper amount of oil. If splashing fails to supply oil to these bearings, the pockets should be filled by hand once a week.

Oil in the crank chamber should not be too thick, but should be of medium or light weight so that the oiling

device can work to the best advantage. A light gas engine cylinder oil is recommended. When the oil in crank chamber becomes muddy it should be removed and replaced by a fresh supply.

Should pounding develop in the compressor, the crank bearings should be inspected, and if found in good condition, it is probable that the cylinder clearance has filled with dirt, or wrist bearings have become defective, and the cylinders should be removed and cleaned and bearings inspected.

In replacing pistons in cylinders care should be taken not to omit any of the little springs in the piston rings.

The machine should be thoroughly inspected from time to time, and bearings should not be allowed to become excessively worn before being replaced.

Brushes should be replaced when worn out, and commutators should be kept smooth, clean and round. Care should be taken not to allow oil to come in contact with the commutator or windings, as oil is injurious to insulating materials.

SUBURBAN MOTOR CAR CATECHISM—CAUSES FOR FAILURE OF TRAIN MOVEMENT.

Question 1. If train fails to move after instructions under train operation have been followed, what should be done?

Answer. Light circuit switches should be closed to ascertain if there is power in the contact rail, or motorman should note if trains in neighborhood are moved by power.

Question 2. If it is found that there is current in operating car, what should be done?

Answer. Master controller handle should be moved to first point, then master controller switch opened to ascertain whether the master control circuits are closed, which will be indicated by the sound of slight arcing at master controller switch.

Question 3. What would cause the failure of train cable circuits?

Answer. First, imperfect master controller fuse. Second, grounded train cable. Third, imperfect contact in master controller. Fourth, loose coupler jumper.

Question 4. What should be done to detect imperfect fuse?

Answer. Insert new fuse, and if this fails it is evident the trouble is elsewhere.

Question 5. What should be done when a grounded train cable occurs?

Answer. The master controller fuse should be replaced and the controller moved to the "on" position to determine if fault lies in construction of the fuse. If this fails, an attempt should be made to locate the ground in the train cable. The first thing to do is to throw the CONTROL CUT-OFF SWITCH (Fig. 502) on the operating car to the "off" position. If this proves ineffective, this operation should be repeated back through the train, cutting out, however, the train cable jumper between car tested and one to be tested.

Question 6. What should be done to detect imperfect contact in master controller?

Answer. Motorman should remove cover from controller and note the movement of contact fingers. The action of the train is dependent upon the contact of these fingers, and if it is found that the contact is imperfect he should endeavor to readjust the contacts, and if he fails in this it is then necessary to operate the train from the next car.

Question 7. What should be done to detect a loose jumper?

Answer. Motorman should lose no time in going back through his train to determine if the coupler plugs are properly inserted in the sockets, and, if not, he should insert them properly.

Question 8. What are the other causes that would prevent the operation of a train or reduce the speed?

Answer. First, the blowing of third-rail shoe fuses. Second, the blowing of main motor circuit fuses. Third, the blowing of circuit breakers or main fuses. Fourth, an imperfectly acting triple valve causing brakes to remain set on one or more cars in train.

Question 9. How can enclosed fuse that is blown be detected?

Answer. If an enclosed fuse has blown there is a deposit or collection of greyish powder at the ends of the box.

Question 10. What should be done in the event of a third-rail shoe fuse blowing?

Answer. This fuse will blow only when there is a short circuit on the car equipment, and fuse should not be replaced but train continued in the regular manner, and report promptly made to the train despatcher or person in charge of nearest terminal.

Question 11. If a circuit breaker acts or blows, what should be done?

Answer. The circuit breaker setting switch should be moved to the "on" position.

Question 12. What should be done when a triple valve acts imperfectly?

Answer. Air-brake instructions should be followed, i. e., valves should be cut out and auxiliary reservoir cock opened to release brakes.

Question 13. If a train is standing on crossover and current cannot be obtained on the operating car, although the other cars of the train and trains in the neighborhood have current, what does this indicate?

Answer. This indicates that the bus line fuses between the operating and adjacent cars have blown, or that bus jumper is loose or disconnected.

Question 14. What should be done to continue operation of train?

Answer. Motorman should go back to the first motor car where current can be obtained and move train through crossover, then go back to the first car again

and proceed in the usual manner until a point of inspection can be reached and inspector notified.

Question 15. If a fire occurs in any car in the train, what should the motorman do?

Answer. Open all circuit breakers by moving the circuit breaker switch (Fig. 485) to the "off" position, and if this fails he should then open the main or motor circuit switch and the main cut-out switch on the car on which the trouble occurs.

Question 16. If smoke or fire is observed by the trainmen in any of the light or heater circuits within the car, what should be done?

Answer. The trainman should immediately cut out the light or heater switches, whichever the case may be, and the trouble be reported to the despatcher in charge of the nearest terminal.

Question 17. If an unusual noise is observed in the movement of train, what should be done?

Answer. To prevent delay the motorman should have the conductor stand beside the train to locate the noise while he moves the train, after which, if the trouble is with the brake rigging, same should be tied up.

Question 18. If the noise is located within the motors, what should be done?

Answer. Motorman should open the cut-out switch on the car affected, and proceed after reporting trouble to despatcher in charge of terminal.

Question 19. If a third-rail shoe support is broken, what should be done?

Answer. Motorman should first pull the bus line jumpers, at both ends of the car, insert wooden insulating slippers between the contact shoe and rail and then proceed to detach or tie up remnants of device, exercis-

ing extreme care that the contact device is kept clear of the truck frame, contact rail, structure, or any grounded parts to prevent injury to himself.

Question 20. If either pilot or emergency air-brake valve leaks badly, what should be done?

Answer. First try applying brakes by releasing the knob in the controller handle several times, and if this does not remedy the defect or difficulty cut the valves out by means of a cut-out cock located in the pipe leading to them from the train line.

ELECTRIC LOCOMOTIVE CATECHISM. CAUSES OF FAILURE OF TRAIN MOVEMENT.

Question 1. If locomotive fails to move after instructions under train operation have been followed, what should be done?

Answer. First, after making sure that the overhead and main master controller switches are closed, throw controller on two or three points and off, and observe by the sound whether any contactors are operating.

Question 2. If none of the contactors operate, what should be done?

Answer. Turn on light circuit switches to ascertain if there is power on the third rail or overhead rail.

Question 3. With current on the locomotive, what would cause the failure of contactors to operate?

Answer. First, an imperfect master controller fuse. Second, imperfect contact in master controller on some of the fingers of the primary cylinder. Third, two or more imperfect 4-ampere fuses in the control apparatus circuits.

Question 4. What should be done to detect imperfect master controller fuse?

Answer. Open main master controller switch and renew fuse, and if there is still no operation of contactors the trouble is evidently elsewhere.

Question 5. How can an enclosed fuse that has blown be detected?

Answer. A small circle in center of table is charred and turned black when fuse is blown. This is termed the "Telltale" of fuse.

Question 6. What should be done to detect imperfect contact in master controller?

Answer. Cut out master controller switch, then remove controller cover and open arc deflectors; first on the right-hand side. Turn on controller and see that the controller fingers make good contact with their respective cylinder segments. If any contact is imperfect endeavor to readjust, if there is time. Failing in this go to the other controller and operate from that, after cutting in its overhead switch and the main master controller switch again.

Question 7. What should be done to detect imperfect fuses in the control apparatus circuits?

Answer. Remove cover from the cut-out switch on back of No. 2 controller and inspect the five top fuses and the eighth and ninth from top. If any one of these fuses shows signs of being blown from the telltale being black, renew the blown fuses.

Question 8. If some of the contactors close on the first test without giving main current, what should be done?

Answer. After opening main switch throw reverser handle back and forth two or three times, throwing controller to first notch at each reversal and note whether both reversers respond, throwing over at each reversal.

Question 9. If neither reverser responds, what should be done?

Answer. Renew fuses eighth and ninth from top on cut-out switch and then try.

Question 10. If one reverser responds to reversals on controller and other does not, what should be done?

Answer. Throw over by hand the reverser that is not operating, making sure after throwing that the reverser is properly locked by toggle. It would require considerable force to lock reverser, but it is absolutely essential that it be locked, and no attempt should be made to operate before making sure of this.

Question 11. What contactors should close on the first notch of controller?

Answer. 1, 2, 4, 19, 22, 25, 33, 41 and 42. Contactors 1, 4 and 19 close after No. 1 reverser thrown; 25, 33 and 41 close after No. 2 reverser throws. Contactors 2, 22 and 42 are governed by the No. 1 circuit on master controller.

Question 12. If contactors 2, 22 and 42 do not close, what should be done?

Answer. First, renew top 4-ampere fuse on cut-out switchboard. Second, examine main motor cut-out switches. See that they are well closed, so that auxiliary contacts are closed.

Question 13. If this is not effective what should be done?

Answer. After closing main switch again throw controller to eleventh notch, moving slowly from tenth to eleventh, and begin operation in series multiple. Motorman should here move handle more slowly than ordinarily, as the automatic feature may thus be cut out. Motorman should watch meter and should not exceed 2,000 amperes in multiple.

Question 14. If two locomotives are being operated together and the master controller fuse blows again, after being removed, what should be done?

Answer. Pull 20-point jumper between locomotives and try renewing fuses, and then operate from locomotive on which fuse does not blow again. If a new 20-point jumper is available this may be substituted and tried.

Question 15. If motors do not take current between eleventh and seventeenth notches or between the eighteenth and twenty-fourth notches, what should be done?

Answer. Renew the second and fifth fuses for the first case and the second and fourth fuses for the second case. If this is not effective examine contact fingers for the primary cylinder and adjust if any of these fingers are not making good contact. Failing in this operate from the other controller.

Question 16. What are the other causes that would prevent the operation of locomotives?

Answer. First, the blowing of the third-rail shoe fuses. Example for this, if lights are not obtainable in turning on light switches (see Q. 2). Second, the blowing of an individual motor fuse.

Question 17. What would tend to reduce the speed?

Answer. First, in operating with two locomotives, if either locomotive is inoperative from any of the causes referred to, or if there is a loose 20-point jumper, or the bus line jumper is loose or out, and the shoe fuses blow on either locomotive, of course one locomotive would be dead load. Second, imperfectly acting triple, as would be indicated by meters showing excessive current.

Question 18. What should be done in the event of third-rail shoe fuses blowing?

Answer. These fuses will ordinarily blow only when there is a short circuit on locomotive equipment. If the cause of fuses blowing is evident, however, as from the

temporary grounding of a shoe, the fuse may be renewed after the ground has been removed. To do this put slipper boards under all the contact shoes of both locomotives and pull bus line jumper between locomotives and release overhead shoes from overhead rail. In removing slippers from under shoes, after renewing fuses, do not stand nearer the fuse box than is absolutely necessary. If one locomotive is grounded and the other is not, leave out bus line jumper and operate from locomotive which is free from ground.

Question 19. What should be done in case of an individual motor fuse blowing, as indicated by contactors 1, 2, 4, 19, 22, 25, 33, 41 and 42 closing properly on first notch without taking current?

Answer. After making sure that the motor cut-out switches over reversers are all closed, open main switch and see which motor fuse is blown, renew this and proceed. If this fuse blows again open cut-out switch for this motor and start train from the eleventh notch.

Question 20. If a third-rail shoe support is broken, what should be done?

Answer. Motorman should first pull bus line jumper if two locomotives are coupled together, insert wooden insulating slippers between the contact shoes and rail on the crippled locomotive and retrieve overhead shoe if upon rail and then proceed to detach or tie up remnant of device, exercising extreme care that the contact device is kept clear of the contact rail and kept clear of truck or any grounded part to prevent injury to himself.

Question 21. What should be done in case air pump fails to operate?

Answer. Renew fuse in pump switch which is located

in "A" end cab. Open the pump switch before doing this. If this does not remedy the trouble inspect the governor contacts and adjust them if necessary.

While many of the conditions referred to are somewhat imaginary and may never arise in practice, the questions and answers given should, however, serve to give the motormen familiarity with the circuits and the operation of the control.

After the motormen have acquired familiarity and experience in electrical operation, they may on occasion exercise their own judgment and common sense to better advantage.

AUTOMATIC AIR-BRAKE CATECHISM.

MOTOR CARS.

A.—General.

Question 1. What is the power used to operate an air-brake?

Answer. Compressed air.

Question 2. How is the air compressed for use in the brake system?

Answer. By air compressors on the motor cars.

Question 3. How does it apply the brake?

Answer. By being admitted to a brake cylinder and forcing a piston out, which, by means of connecting rods and levers, pulls the brake shoes against the wheels.

Question 4. How is the brake released?

Answer. By allowing the air in the brake cylinders to escape to the atmosphere. A spring in the brake cylinder then shoves the piston back and the brake shoes are forced away from the wheels by the brake release springs on the trucks.

Question 5. What is the form of air-brake now generally used?

Answer. The quick-action automatic brake.

Question 6. Why is it called an automatic brake?

Answer. Because if anything, no matter what, causes a reduction of pressure in the brake pipe, the brake will apply automatically.

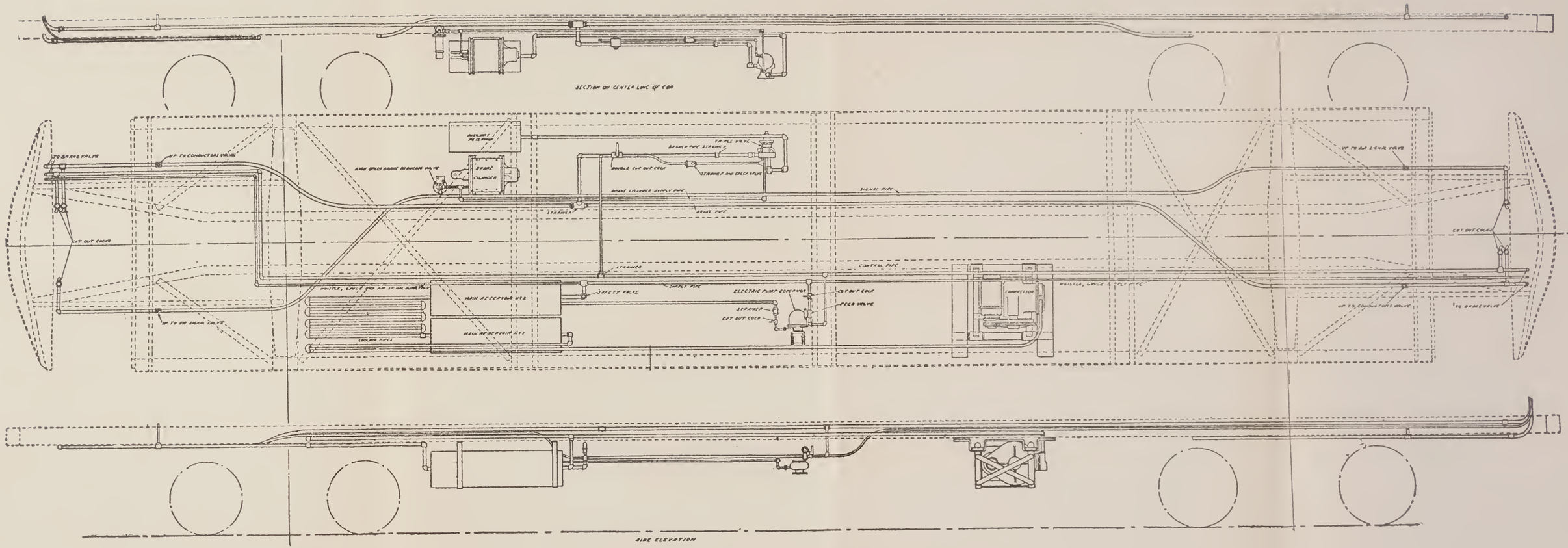
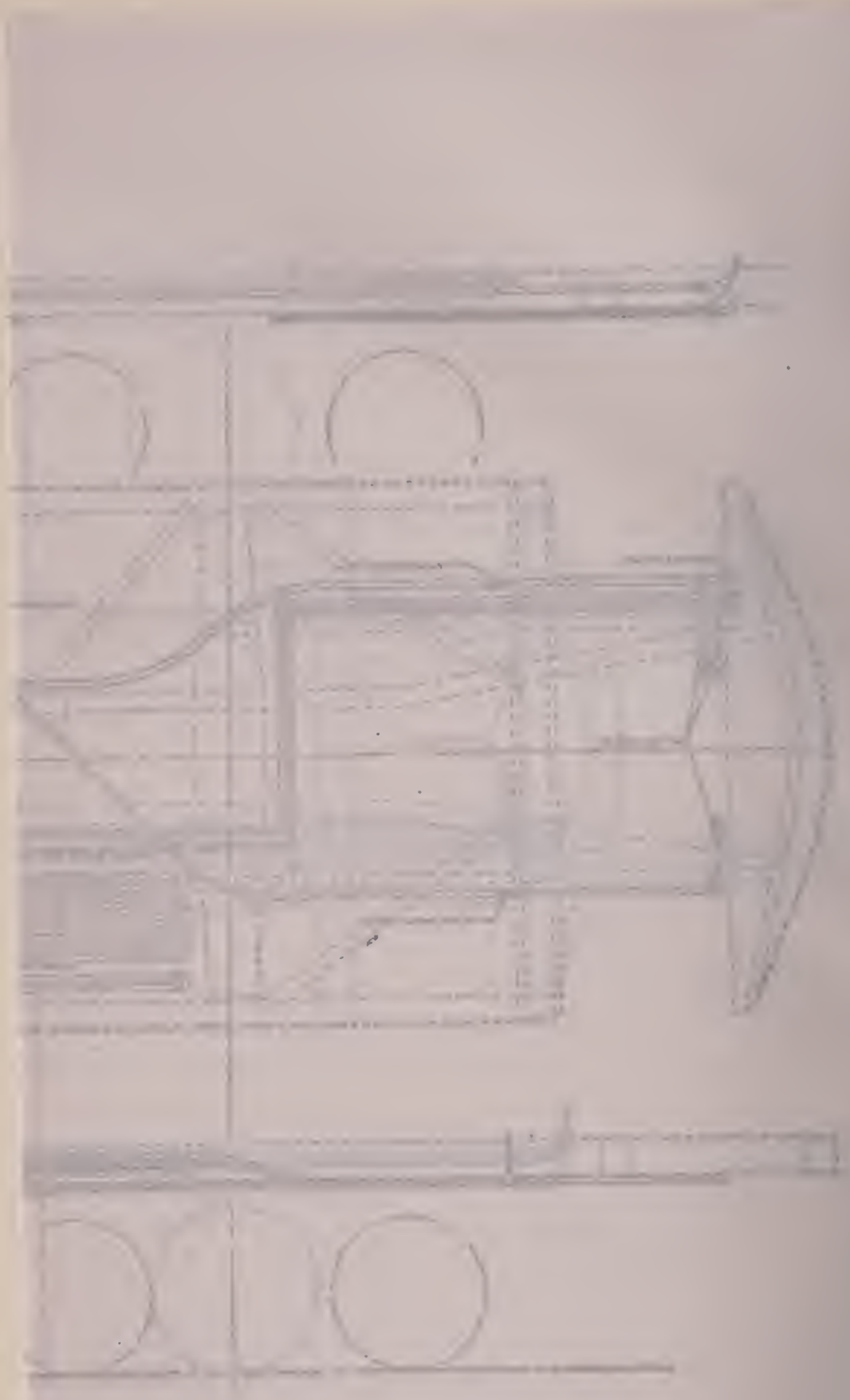


Fig. 524. Arrangement of Air Brake Apparatus on Car.



Question 7. What parts has the quick-action automatic brake on a motor car?

Answer. An air compressor, pump governor, two main reservoirs, safety valve, slide-valve feed valve, control pipe, two brake valves, two air gauges, brake pipe, triple valve, auxiliary reservoir, brake cylinder, conductor's valve, two air strainers, one bleed cock, two pair of hose and couplings, six cut-out cocks, one double cut-out cock, one air strainer with check valve, and one branch pipe air strainer (Fig. 524).

Question 8. Where are the brake valves and air gauges located?

Answer. In the motorman's cab at each end of the car.

Question 9. What parts has the quick-action brake on a trailer car?

Answer. Auxiliary reservoir, brake cylinder, triple valve, brake pipe, control pipe, conductor's valve, two air strainers, one bleed cock, four cut-out cocks, two pair of hose and couplings, one double cut-out cock, one air strainer with check valve, and one branch pipe air strainer.

Question 10. Is there any difference between the reservoirs, triple valves, and brake cylinders used on motor cars and trailer cars?

Answer. No.

Question 11. Where is the pressure that supplies the brake cylinder stored or carried with the automatic system?

Answer. In the auxiliary reservoir under each cab.

Question 12. What has to be done to apply the automatic brake?

Answer. Reduce the brake-pipe pressure, which reduction causes the triple valve to admit the pressure from the auxiliary reservoir to the brake cylinder.

B.—The Air Compressor.

Question 13. Where is the compressor installed, and how?

Answer. It is placed under the car, suspended from the sills by a cradle. (See Fig. 525).

Question 14. Does it make any difference in which direction the compressor rotates?

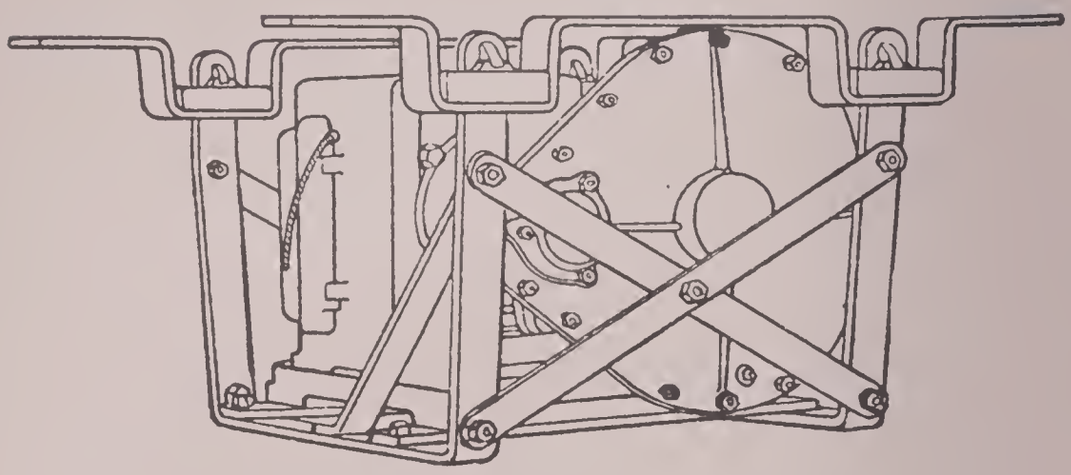


Fig. 525. Suspension Cradle of Air Compressor.

Answer. The shaft must always turn so that the compression part of the stroke is on the upper half revolution. This will be assured if the rotation is the same as the hands of a clock when looking at the compressor at the gear side.

Question 15. How are the pump parts lubricated?

Answer. The crank case is filled with oil (preferably Arctic Ammonia Oil) up to a point determined by the oil fitting 18, Fig. 526, on the side of crank case. When the level of the oil is visible in this fitting, the cap being removed, the oil level in the crank case is correct. As

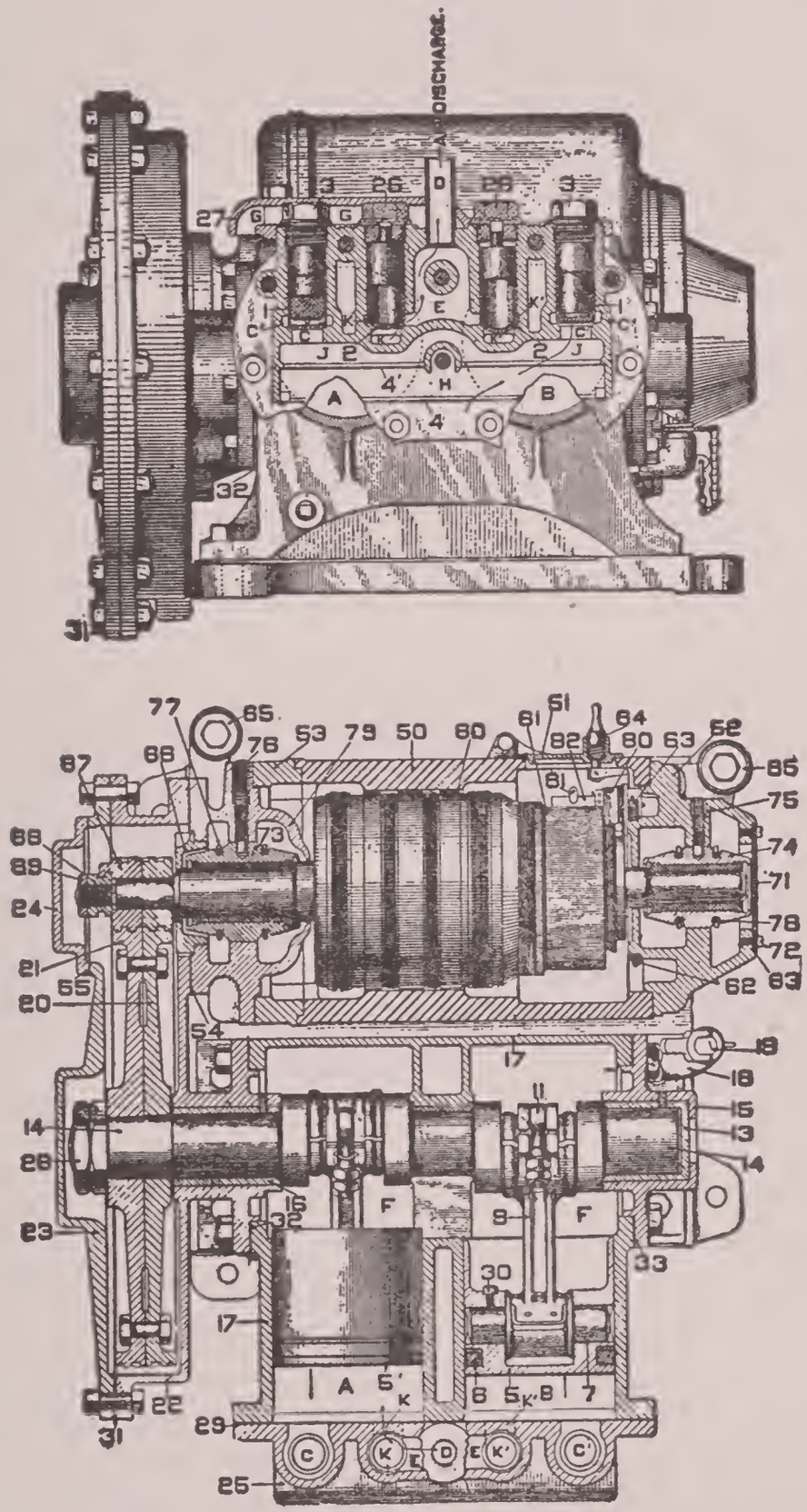


Fig. 526. Air Compressor on Motor Cars.

the shaft turns and the connecting rod heads are forced downward, they drive the oil over the inside of the crank case and such parts of the cylinders as are exposed. In this manner all the crank-shaft bearings as well as the cylinders themselves and wrist pins are thoroughly lubricated.

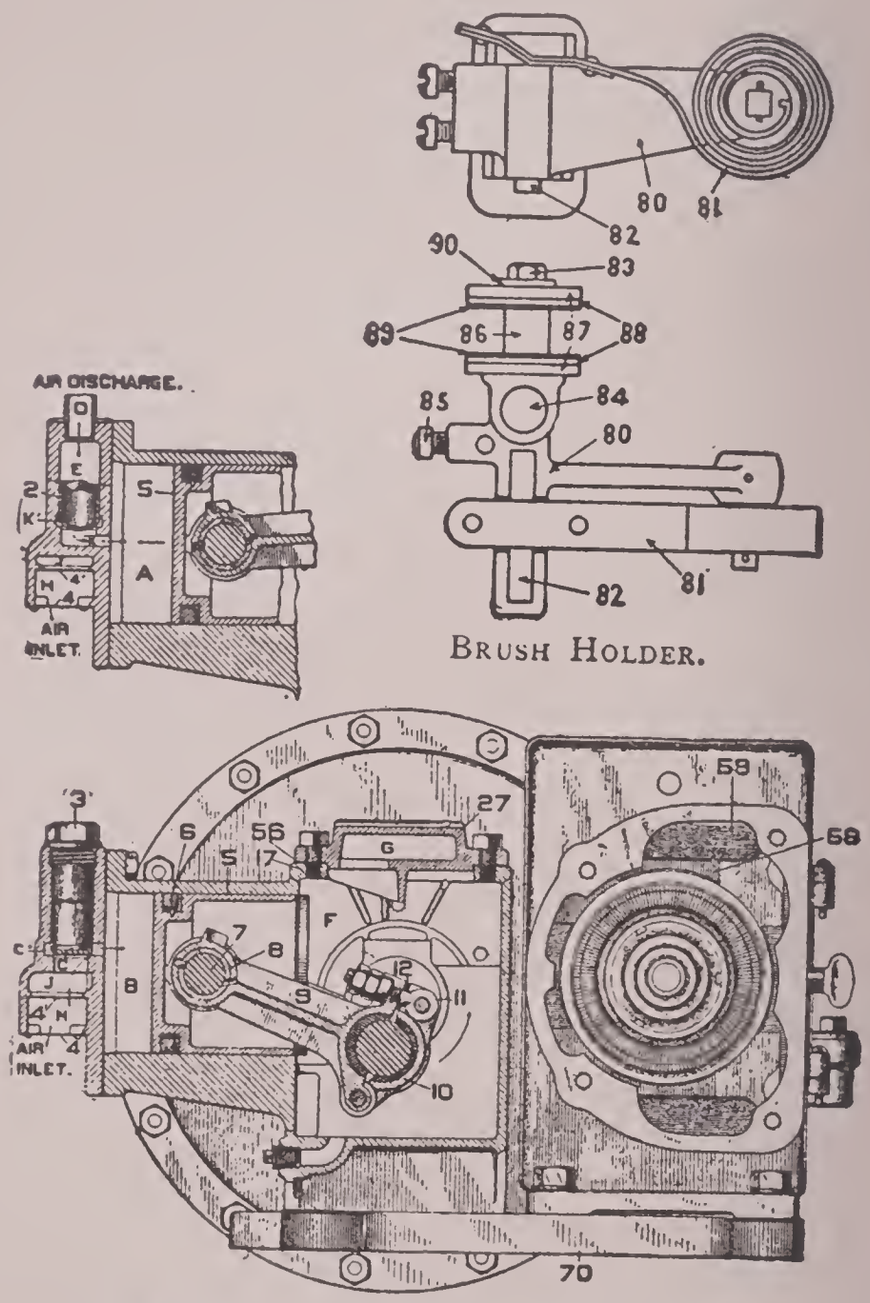


Fig. 527. Air Compressor on Motor Cars.

Question 16. How often should the oil in the crank case be replenished?

Answer. Once a week.

Question 17. How often should the suction box be cleaned?

Answer. This depends largely upon the locality in which the car operates. Generally it is not required more than once or twice a month. In very dusty localities it may be required oftener.

Question 18. How is the suction box cleaned?

Answer. The outer perforated plate 4 (Fig. 527) covering the air inlet on the lower side of chamber H should be removed and the pulled curled hair taken out and thoroughly cleaned by beating in a bag, by the use of compressed air or some other efficient means. It may then be replaced and the outer perforated plate put back in place.

Question 19. How is the motor lubricated?

Answer. By removing plug 65 (Fig. 526) in both end bearing housings and filling with oil until the level can be plainly seen. These bearings should be replenished at the same time as the crank case.

Question 20. Should a compressor which frequently blows fuses be sent out temporarily with a heavier fuse than that prescribed?

Answer. Not under any circumstances. Such a practice is almost sure to result in burning out the motor.

C.—Electric Pump Governor.

Question 21. What is the purpose of the electric pump governor? (Fig. 528).

Answer. It starts and stops the compressor automatically when certain predetermined minimum and maxi-

mum air pressures occur in the main reservoir by alternately making and breaking the circuit to the air-compressor motor.

Question 22. Where is this governor located?

Answer. It is placed in a sheet-iron box under the

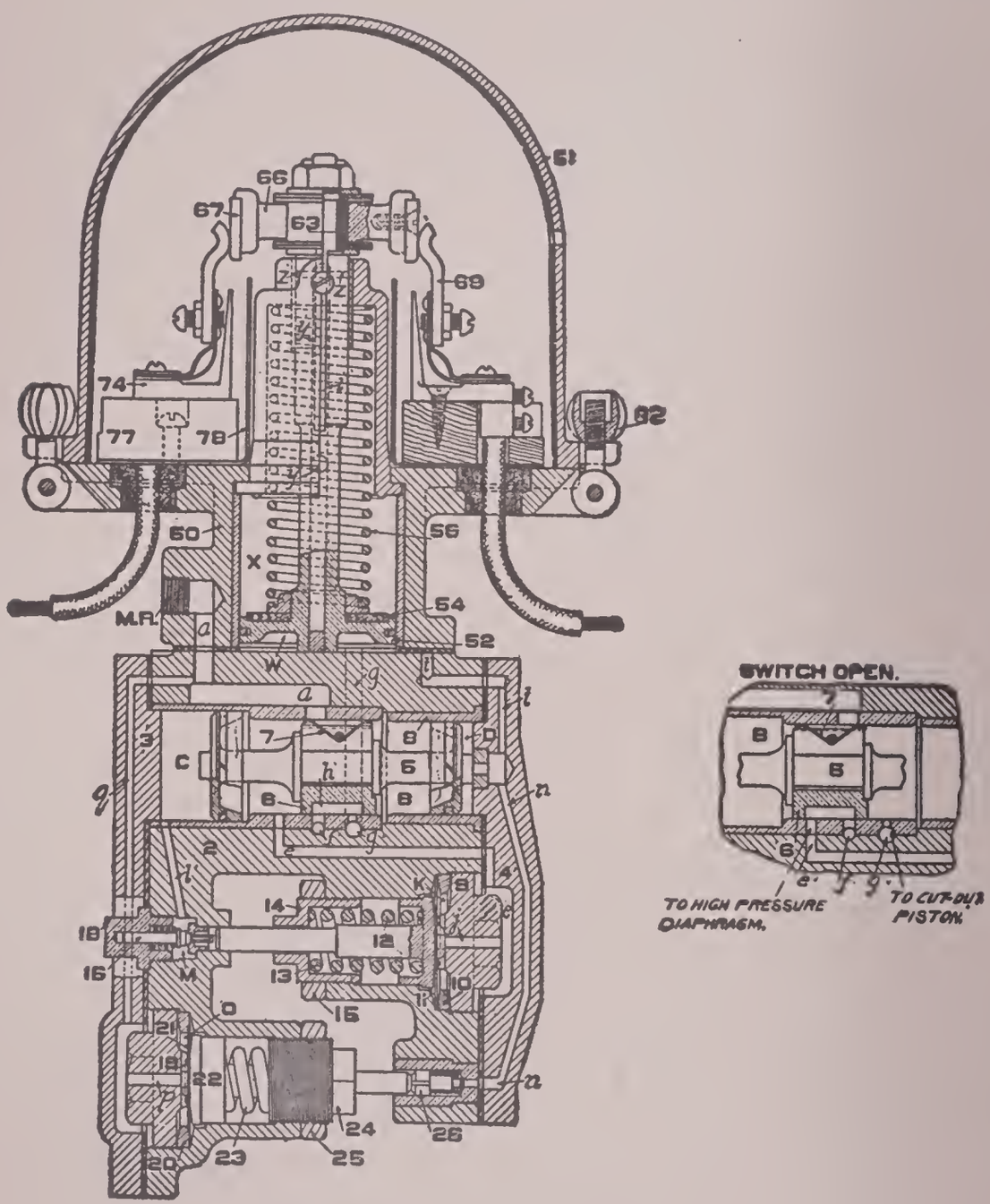


Fig. 528. Air Compressor Governor on Motor Cars.

car on the motor compressor side. This box is located between the grid resistances.

Question 23. At what pressure is the governor set to start the compressor?

Answer. One hundred and five pounds.

Question 24. At what pressure is the governor set to stop the compressor?

Answer. One hundred and twenty pounds.

Question 25. Why is there such a difference between the maximum and minimum pressures?

Answer. By having this difference a number of applications of the brake can be made before reducing the main reservoir pressure to the cutting-in point. This gives the compressor a longer rest between periods of operation, thereby allowing it more time to cool.

D.—The Main Reservoirs.

Question 26. From the compressors where does the air pressure go?

Answer. To the main reservoirs.

Question 27. Where are the main reservoirs located?

Answer. Under each motor car.

Question 28. How much main-reservoir pressure should be carried?

Answer. One hundred and twenty pounds maximum and 105 pounds minimum.

Question 29. How often should the reservoir be drained?

Answer. Daily.

Question 30. From the main reservoir where does the air go?

Answer. Through the feed valves to the control pipe and thence to the motorman's brake valve.

E.—Safety Valve.

Question 31. What is the purpose of the safety valve? (Fig. 529).

Answer. It prevents overcharging of the brake system in case the electric pump governor fails.

Question 32. Where is it placed?

Answer. In the end of the main reservoir.

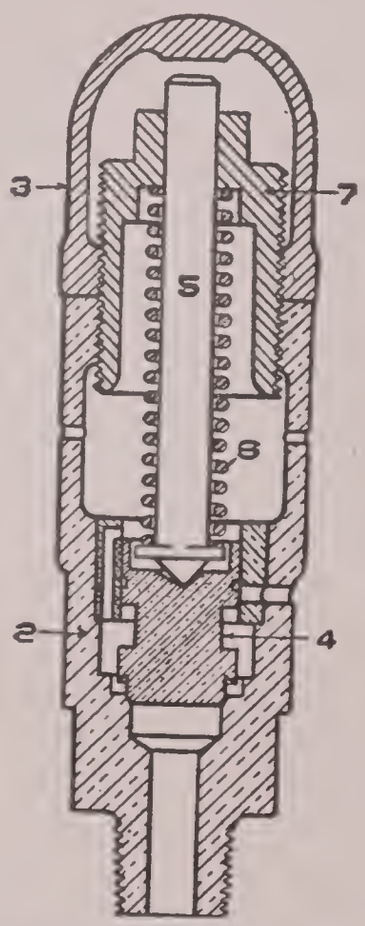


Fig. 529. Safety Valve.

F.—Slide-Valve Feed Valve.

Question 33. From the main reservoir, where does the air go?

Answer. To the slide-valve feed valve (Figs. 530 and 531).

Question 34. Where is it located?

Answer. In the box under the car between the resistances on the motor compressor side, in which the electric pump governor is also located.

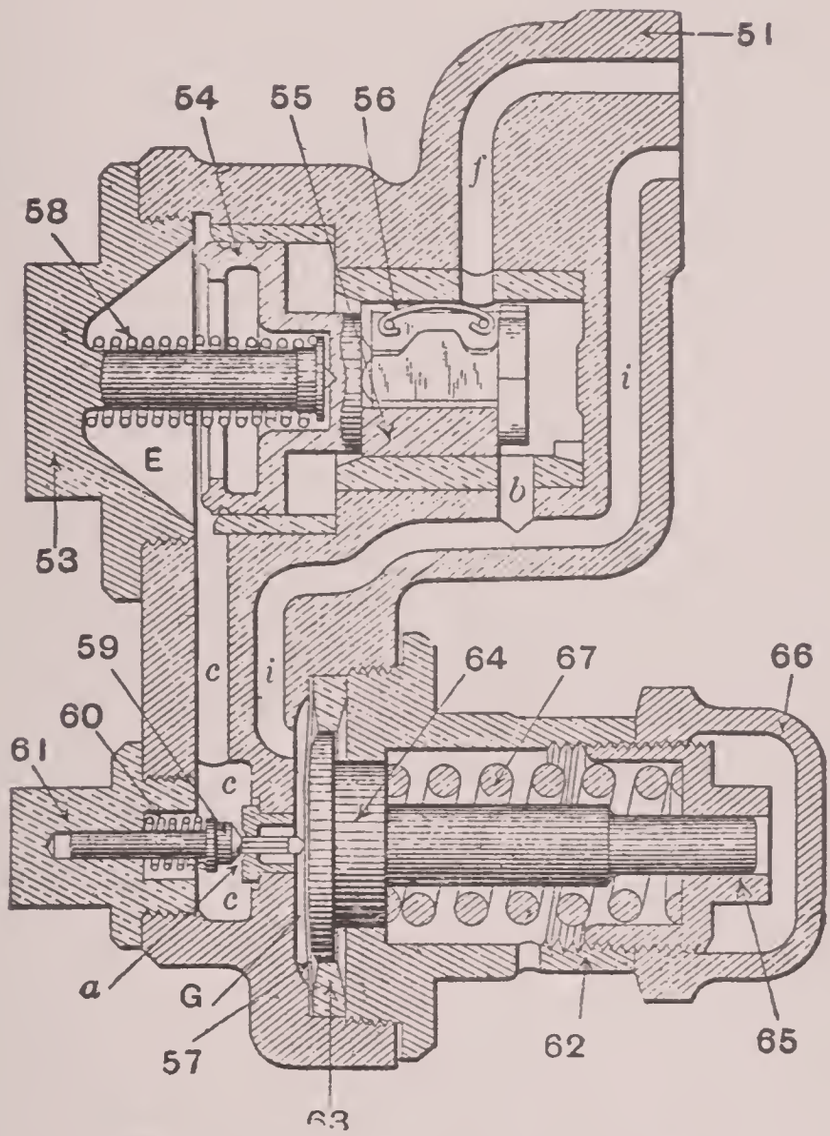


Fig. 530. Slide Valve—Feed Valve Open.

Question 35. What is meant by the slide-valve feed valve?

Answer. It is a device in the pipe from the main reservoir to the control pipe which automatically reduces

main-reservoir pressure to a constant control-pipe pressure.

Question 36. What tends to lower the control pipe pressure, thereby causing the slide-valve feed valve to act?

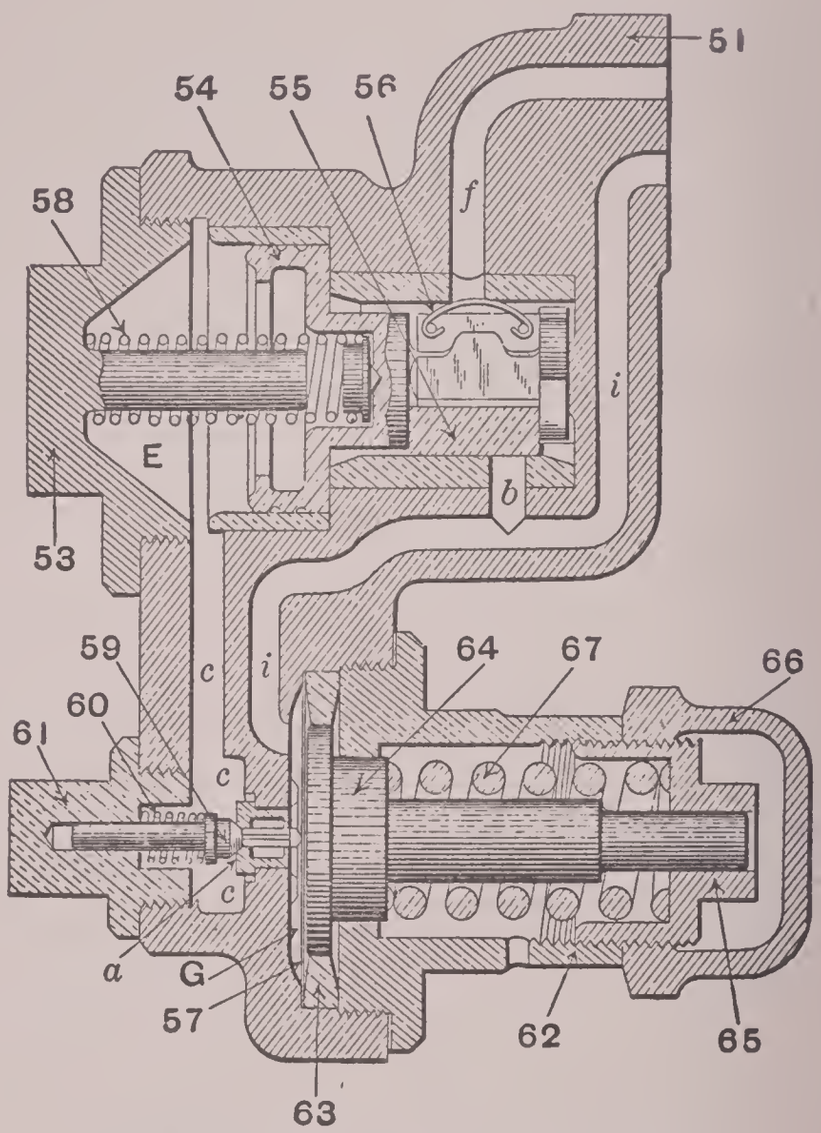


Fig. 531. Slide Valve—Feed Valve Shut.

Answer. Reinstating the brake-pipe pressure at release; recharging the auxiliary reservoirs; maintaining an air pressure of 90 pounds in the system against leakage, when the brakes are not applied.

Question 37. What care should be given this feed valve?

Answer. The piston and its slide valve should occasionally be taken out, all dirt and gum removed from them and the chambers where they work, being careful to leave no lint and to avoid bruising the parts removed. A very small amount of some light lubrication oil (engine oil will do in the absence of a better) should be applied to the piston, the face of the slide valve and the spring on the latter. In replacing the parts move them back and forth a few times to insure that they work freely. Next, remove the regulating valve, carefully clean it, its valve seat and the bushing through which the valves extend, using no metal to do this, so as to avoid scratching, and replace the valve dry.

Question 38. Must the main reservoir be drained to do this?

Answer. No. Close the cut-out cock between the feed valve and the main reservoir.

Question 39. When properly regulated, what can cause pressure to feed too high in the control pipe?

Answer. A leaky slide valve.

Question 40. What will tend to prevent the feed valve properly maintaining the pressure in the control and brake pipes?

Answer. A leaky regulating valve, leakage past cap nuts. If this leakage is great enough the effect will be the same as opening the regulating valve.

Question 41. What will tend to prevent the feed valve from opening promptly?

Answer. The piston becoming heavily coated with a greasy deposit, which prevents rapid equalization of the

pressure on both sides of the piston, thus reducing its sensitiveness.

Question 42. Should the feed valve be carefully regulated?

Answer. As there are a number of these valves in a train they should all be regulated alike as nearly as possible, since that valve which is regulated the highest will stay open the longest and furnish the most air, thus making the work imposed on the compressor of that car more than that done by the others.

G.—Control Pipe.

Question 43. After leaving the feed valve, where does the air go?

Answer. Through the control pipe to the brake valve that is being operated by the motorman.

Question 44. What is the purpose of the control pipe?

Answer. It is the means of conveying to the brake valve that is being operated by the motorman the supply of air furnished by all the main reservoirs of the train.

Question 45. What are the connections to the control pipe?

Answer. From the feed valve; to the brake valve, and to the triple valve.

Question 46. What pressure is maintained in the control pipe?

Answer. Ninety pounds.

Question 47. Does this pressure vary during the application of the brakes?

Answer. No.

H.—The Motorman's Brake Valve.

Question 48. From the feed valves, where does the air go?

Answer. Through the control pipe to the brake valve being operated by the motorman.

Question 49. From the feed valves to the control pipe to the brake valve is all what pressure?

Answer. Ninety pounds.

Question 50. It passes through the brake-valve into what?

Answer. The brake pipe, and thence through the triple valve to the auxiliary reservoir.

Question 51. What is the purpose of the brake valve?

Answer. To connect the control pipe to the brake pipe; to release the brakes, charge the system and maintain the pressure; to connect the brake pipe through suitable passages to the atmosphere to apply the brakes, and to break all connection between the brake pipe and control pipe or atmosphere; to hold the brakes applied.

Question 52. In what position of the brake valve is there a direct opening from the control pipe to the brake pipe?

Answer. In release or running position.

Question 53. In this position how would the control pipe and brake-pipe pressure stand, comparatively speaking?

Answer. Equal.

Question 54. What is the release or running position to be used for?

Answer. For recharging the brake pipe quickly, so as to insure a prompt and simultaneous release of the

brakes; for recharging the auxiliary reservoir, and prevent brake-pipe leakage from setting the brakes.

Question 55. What is the next position of the brake valve and what does it signify?

Answer. Lap position; all ports closed.

Question 56. When is it used?

Answer. When holding the brakes on after an application; or when graduating the release; or when they have been applied by opening a conductor's valve. This position should also be promptly used when train breaks in two; hose becomes uncoupled or bursts; when coupling to air-brake cars or at any time a sudden reduction of brake-pipe pressure takes place when not made by the motorman himself.

Question 57. How should the brake-valve handle be turned to lap?

Answer. Slowly after making a brake-pipe reduction so as to cut off the exhaust gradually, that the head brakes will not be "kicked off" by the air surging forward; quickly when going to the release position, to graduate the release.

Question 58. Why should it be returned quickly when graduating the release?

Answer. Because the longer the brake-valve handle is in the release position the lower the brake-cylinder pressure will reduce. In other words, the reduction of brake-cylinder pressure is governed by the same principle as the increase of brake-cylinder pressure during an application, but oppositely. For example, the increase of brake-cylinder pressure up to the point of equalization is proportional to the decrease of brake-pipe pressure; on the other hand, the decrease of brake-cylinder pressure is proportional to the increase of brake-pipe pressure.

Question 59. What is the next position and its use?

Answer. Service application; should be used for all ordinary stops.

Question 60. How is the air discharged from the brake-pipe in making a service application?

Answer. Through ports in the rotary valve of the brake-valve, and the "quick service" ports of the triple valve. The further the brake-valve handle is moved in the service-application direction the more rapid the discharge of air.

Question 61. Would the blow, or escape, of air from the brake-pipe be longer with a six-car train than with a three-car train, the same reduction in pounds being made in each case?

Answer. Yes; if the brake-valve handle is moved to the same notch in both cases. The capacity of the long brake-pipe being so much greater it would require a larger volume of air to escape to make the same reduction in pounds.

Question 62. How many service-application notches has the brake-valve?

Answer. Two: service and intermediate service.

Question 63. When should they be used?

Answer. With a six-car train the brake-valve handle can be moved to the second service-application opening, but with not more than three or four cars the first or intermediate notch should be used.

Question 64. Why not use the service notch with a three or four-car train?

Answer. Because owing to the comparatively short brake-pipe the reduction of brake-pipe pressure would be sufficiently rapid to cause quick action, resulting in a full emergency application of all the brakes when only partial service application was intended.

Question 65. What is the next position?

Answer. The emergency or quick-action; in this position a large direct opening is made from the brake-pipe to the atmosphere.

Question 66. When is this position to be used, and how?

Answer. Only in case of emergency; and then the handle should be moved directly to that position and allowed to remain there until the train stops or the danger is passed.

I.—Brake-Pipe.

Question 67. What is the purpose of the brake-pipe?

Answer. It is the connection between the brake-valve and the triple valves, auxiliary reservoirs and brake cylinders.

Question 68. What is the difference in pressure between the brake-pipe and the control pipe?

Answer. When the brake-valve handle is in full release there is no difference; during an application of the brakes the brake-pipe pressure is lower than the control pipe, an amount depending on what brake-pipe reduction is made by the motorman.

Question 69. What special devices are placed in the connection from the brake-pipe to the triple valve?

Answer. The double cut-out cock and the branch-pipe air strainer.

Question 70. What is the double cut-out cock?

Answer. It is a cock having two entirely separate passages through it, one tapped at each end for one-inch pipe and the other for three-eighth-inch pipe. The larger one is for the branch pipe from the brake-pipe to the

triple valve, and the smaller one for the branch pipe from the control pipe to the triple valve. The turning of the cock handle shuts off communication from both the brake-pipe and the control pipe to the triple valve. (Fig. 532).

Question 71. Why should it be arranged to shut off communication from both the brake-pipe and the control pipe to the triple valve at the same time?

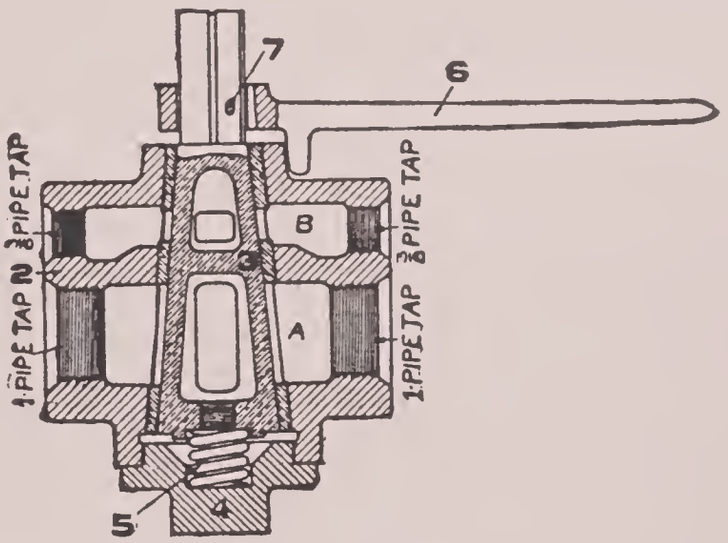


Fig. 532. Double Cut-out Cock.

Answer. It makes it impossible in case anything should happen to the brake cylinder, reservoir or triple valve to cut them out from one of these pipes and not from the other, which might easily occur if a single cock were placed in each of the branch pipes separately.

Question 72. When is the double cut-out cock to be closed?

Answer. Only when the brake apparatus on that car becomes out of order sufficiently to make it inadvisable to use it.

Question 73. What is the purpose of the branch-pipe air strainer?

Answer. It prevents dirt and scale from entering the triple valve, where it might result in cutting the slide valve and piston; or during an emergency application lodge on the emergency valve and hold it open.

Question 74. How are connections made between the cars?

Answer. By hose and couplings.

Question 75. What is it necessary to do when coupling or uncoupling hose connections between cars?

Answer. To uncouple it is necessary first to close the cocks at the end of each car, both for the brake-pipe and the control pipe, before attempting to uncouple the hose. In coupling it is necessary to see that the hose couplings for both the pipe lines are securely made before opening the cocks in each pipe on the cars; open the cocks of the control pipe FIRST, and AFTERWARDS those in the brake-pipe.

Question 76. In making up trains what should be done with the hose couplings at each end of the train?

Answer. They should be fastened up to the dummy couplings which are supported on the end of the car in order to keep any dirt or foreign matter from getting into the couplings and pipes, and to prevent anything lying in the track from striking them. Also, to reduce the wear due to the swinging of the hose when free.

J.—The Triple Valve.

Question 77. To what is the brake-pipe connected under the car?

Answer. The triple valve.

Question 78. Where is it located?

Answer. On a bracket in a special box underneath the car, between the grid resistances, on the side opposite to the box containing the electric pump governor and feed valve.

Question 79. Why is it called the triple valve?

Answer. Because of the three distinct operations it performs in response to variations of brake-pipe and auxiliary reservoir pressures. It (1) charges the auxiliary reservoir; (2) applies, and (3) releases the brakes.

K.—Auxiliary Reservoir.

Question 80. What is the auxiliary reservoir?

Answer. It is a wrought steel reservoir in which is stored the air for applying the brakes on the car to which it is attached.

Question 81. To what is it connected?

Answer. Its only connection is to the triple valve.

L.—Brake Cylinder.

Question 82. What is a brake cylinder?

Answer. It is the cylindrical casting secured to the car framing at the side of the auxiliary reservoir. It is provided with a piston having an air-tight leather packing and a hollow piston rod. This piston, together with the cylinder and the head on the packing leather side, form a chamber into which the compressed air is admitted from the triple valve, and by forcing the piston outwardly applies the brakes to the wheels by means of foundation brake gear and brake shoes to which it is attached by a loose push rod; a head on the other end of the cylindrical casting forms the guide for the piston and a seat for a coiled spring by which the piston is forced

back to the inner end of its stroke when the air pressure is exhausted from the brake cylinder by the operation of the triple valve.

M.—Levers.

Question 83. How is the piston rod connected to the brake shoes?

Answer. By a system of levers generally called "foundation brake gear." When the piston is pushed out the levers are so arranged as to draw the shoes up against the wheels. (Fig. 533).

Question 84. What is especially necessary in arranging these levers?

Answer. That the retarding effect on each wheel should be in proportion to the weight of the car bearing upon it and that it should be equal for both wheels on the same axle. When a car weighs equally on all the axles the brake-shoe pressure should be equal on all the wheels.

Question 85. How is the necessary brake-shoe pressure against the wheels determined?

Answer. By the light weight of the car.

Question 86. What proportion of light weight is taken as a basis for the brake-shoe pressures?

Answer. The total pressure of the brake-shoes against the wheels should be 100 per cent of the weight of the motor cars and 90 per cent of the light weight of the trailer cars.

Question 87. What is the general arrangement of foundation brake gear?

Answer. Fig. 533 shows the general arrangement of brake rods and levers and their relation to the brake

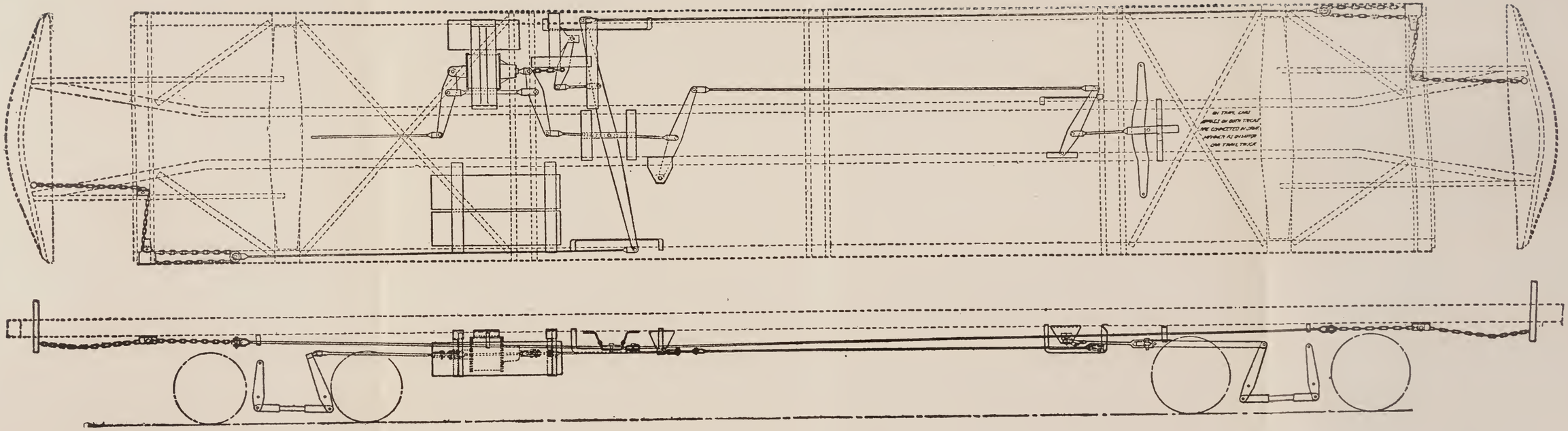
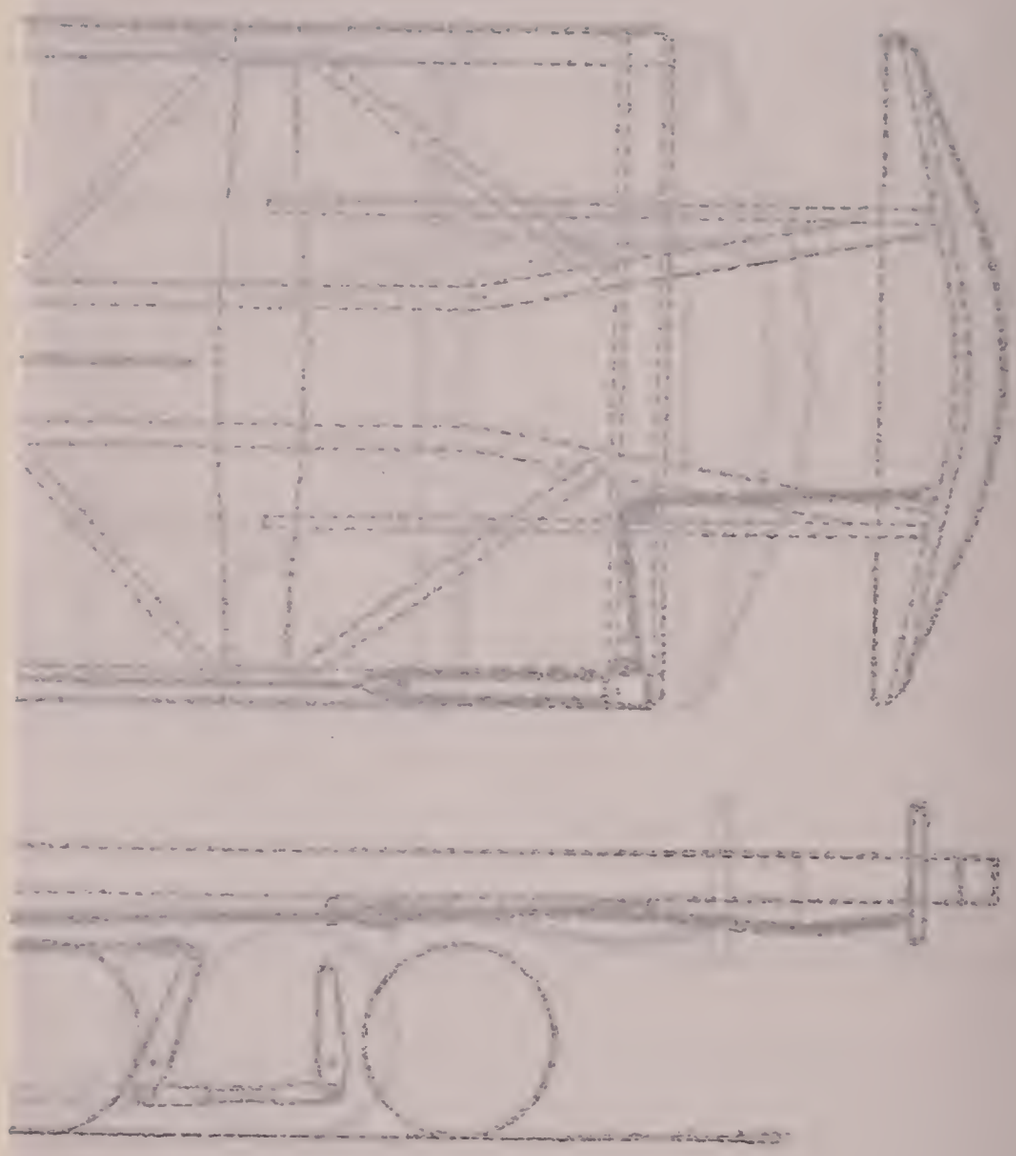


Fig. 533. Arrangement of Brake Levers.



cylinder. To the push rod is connected the PUSH-ROD LEVER. A similar lever, called the CYLINDER LEVER, is attached to the slack adjuster and connected with the push-rod lever by the CYLINDER ROD. Through these two levers the pressure developed in the brake cylinder is carried to each of the trucks. As the piston is pushed out by the air pressure the upper end of the push-rod lever is forced to the left. This transmits the force through the cylinder rod to the cylinder lever, and as a result the lower ends of both levers are drawn together, transmitting a pulling force through both of the TRUCK PULL RODS. The push-rod and cylinder levers are so proportioned that the amount of force transmitted to each truck is in the same proportion as that of the weight of the car resting on each truck. The amount of pull transmitted to each of the truck pull rods is equal.

The truck pull rod engages with the upper end of the LIVE TRUCK LEVER. The lower end of the live truck lever is connected with the lower end of the DEAD TRUCK LEVER by a TIE ROD. These truck levers are proportioned, so that each brake beam gets an amount of pressure in proportion to the weight on that axle.

Question 88. What is the total leverage?

Answer. It is the ratio* of the sum of the pressures on all the wheels of the car to the pressure on the push-rod.

Question 89. How is the hand-brake connected to the lever system?

Answer. Through the HAND-BRAKE ROD, HAND-BRAKE LEVER, HAND-BRAKE CONNEC-

*Ratio: The quotient obtained by dividing one into the other is obtained. Suppose it is 7. Then we say the ratio is 7 to 1.

TION, MULTIPLYING LEVER, and the chain which connects the multiplying lever to the push-rod.

Question 90. What is the use of the chain?

Answer. It provides a flexible connection between the hand-brake and power-brake rigging, so that when the power brake is in operation the hand-brake levers do not move, thus reducing the amount of friction to be overcome by the air pressure and also reducing the wear on the hand-brake rods and levers.

Question 91. What is the object of the multiplying lever?

Answer. To increase the power of the hand-brake to that ordinarily obtained by the air pressure.

Question 92. When applying the brakes by hand does the piston in the brake cylinder move out?

Answer. No. The push-rod is loose in the push-rod holder and can be forced out by the piston, but cannot pull the piston out when it is pulled out.

N.—General Operation.

Question 93. How should brakes be tested in preparing trains for service?

Answer. First, see that hose coupling cut-out cocks on the head and rear end of train are closed and those between the cars are opened. Next, that all the brake valves are lapped with the exception of the one that is to be used, and this must be placed in release position. Then start the compressors, charge the brake-pipe and auxiliary reservoirs, allowing the compressor to operate until the governor cuts it out. Motorman will then apply brakes by moving handle of brake valve to service-application notch until a reduction of ten pounds has been

made in the brake-pipe. Then after placing handle on lap, remove handle, and carrying same, motorman will proceed throughout length of train and see that each cylinder piston of every car has moved out such a distance as to indicate that brakes are properly applied on all cars of the train. The brakes are then to be released from the last cab at end of train. Then again remove handle, and return to other end of train, examining all cylinder pistons. Be careful to see that they have moved back to full release, thus indicating that all brake shoes hang free.

Question 94. In making an application of the brakes for any purpose, except testing brakes or emergency applications, what is the least pressure that should be drawn from the brake-pipe at the first reduction?

Answer. Five pounds.

Question 95. Why not less than this amount?

Answer. Because the reduction might not be sufficient to force the brake piston against the release spring and friction of brake rigging.

Question 96. What reduction of train-line pressure is necessary to fully apply the brakes on service application?

Answer. From eighteen to twenty pounds.

Question 97. Why should the reduction, as stated in the last question, fully apply the brakes?

Answer. Because eighteen to twenty pounds reduction in brake-pipe pressure causes an equalization of auxiliary reservoir and brake-cylinder pressure, thus fully applying the brakes. A further reduction in the brake-pipe is simply a waste of air.

Question 98. What is the possible result of this waste of air?

Answer. The brakes are slower in releasing, fail to

release simultaneously, cause a shock to the train upon stopping, and seriously overtax the compressor.

Question 99. How many applications should be made in making the ordinary service stop?

Answer. As a general rule, one.

Question 100. What is meant by one application?

Answer. From the time the brakes are applied until they are fully released, no matter how many brake-pipe reductions or graduated releases, is one application; after the brakes have been fully released, and are reapplied, is a second application.

Question 101. How is the application to be made for an ordinary service stop?

Answer. A fifteen to eighteen-pound brake-pipe reduction should be made obtaining a full cylinder pressure at once, if at fair speed and gradually reducing same as the speed of the train decreases.

Question 102. Should this plan of operation invariably be followed?

Answer. No. If the train is drifting or running at very low speed it is not necessary to have such a high cylinder pressure.

Question 103. Why is it that the cylinder pressure should be gradually released as the speed of the train decreases?

Answer. Because the friction between the brake-shoes and the wheels is less for high speed than for low, having the same pressure in both cases. Consequently, if maximum cylinder pressure is used at a high speed it is necessary to decrease it as the speed decreases; also to make stop in less time and to avoid rough stops; also stops can be made much more accurately; otherwise, skidding of the wheels would be likely to follow at low speeds.

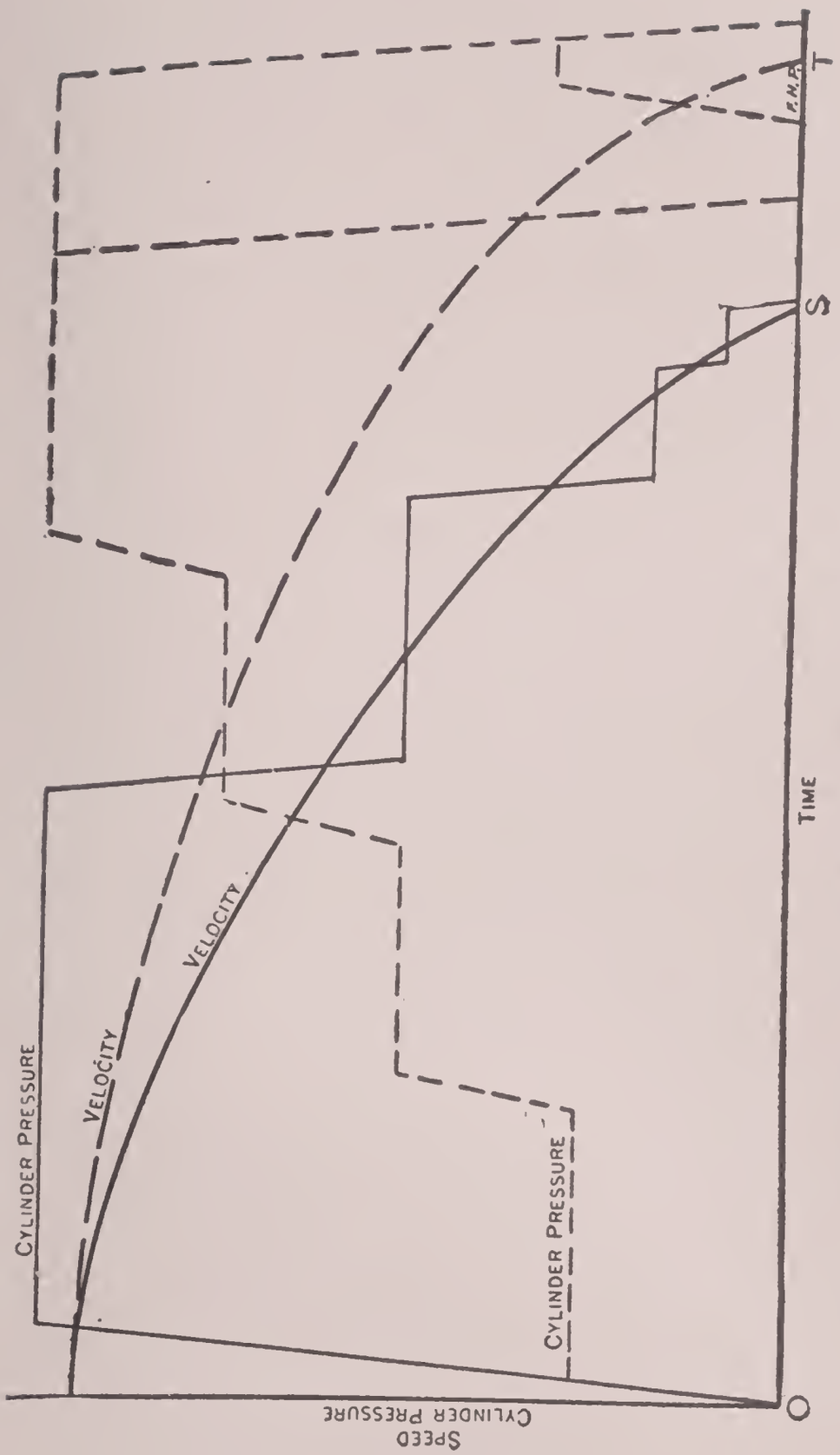


Fig. 534. Diagram of Stops.

Question 104. What would be the result if the cylinder pressure should be gradually increased during the application?

Answer. Pressure would be least when the speed was greatest, and, therefore, have a much smaller retarding effect than it ought to; and would be greatest when the speed was considerably reduced, thereby making the skidding of the wheels very probable and bring the train to a stop with a sudden jerk.

Fig. 534 illustrates the proper and improper method of handling the brakes in a service application. The brakes are applied at o and the train comes to a stop at S or T. The curve shows the decreasing velocity after the brakes are applied. The diagram shows the variations of cylinder pressure during the stop. The full lines show the proper method of handling, and the dotted lines the improper. It will be seen by the dotted diagram and curve that the retardation of the train during the first part of the stop is comparatively small. The motorman is afraid to put on his brakes, and as a result applies them little by little, till at the end of a stop he has full cylinder pressure, and the retardation of the train is very sudden and dangerous. Often motormen will find, when using such a method, that he has to make full release of the brakes and then reapply, as shown on the diagram, in order to keep the train from stopping short of the station. This causes jerks and uneven motion throughout the train and a great waste of air, resulting in overworking the compressor and causing unnecessary wear on the train apparatus.

On the other hand, if the motorman throws full pressure at once into the cylinder the retardation during the first part of the stop is much greater, and as the speed

gradually decreases, the motorman gradually releases the cylinder pressure in such a way as to keep the retardation of the train at a maximum. The amount gained in retardation during the first part of the stop by the proper method of braking makes the time required for the entire stop much less than in the other case, the time saved being represented by the distances S T.

Question 105. What other reason is there besides making quicker stops for using the proper method of braking outlined above?

Answer. By gradually releasing the brakes the auxiliary reservoirs are partially recharged at each partial release, till when the train comes to a stop the auxiliary reservoirs are almost completely recharged. In the other case, when the train comes to a standstill the brake-pipe pressure is the least of any time during the stop, so that the entire system has to be completely recharged after the train comes to a standstill. This means, in the latter case, more time is required for the brake system to be fully prepared for subsequent applications. Also with proper method start can be made quickly if desired, as there is little, if any, cylinder pressure remaining. This is also true if grade necessitates holding brake on during stop, as it can be graduated almost off.

Question 106. In making partial release during a brake application, how should the brake valve be handled?

Answer. It should be moved to the release position for a moment and immediately returned to lap.

Question 107. To make a complete release of brakes, how should the brake-valve be handled?

Answer. It should be moved to the full release position and allowed to remain there.

Question 108. If brakes release after a service-application, where should cause be looked for?

Answer. Examine brake valves in train until trouble is located. Either a brake-valve has not been fully lapped or has a leaking rotary valve.

Question 109. In case of emergency, when it is essential to stop the train in the shortest possible distance, how should the brake-valve be handled?

Answer. The handle should be thrown to the full emergency position and left there until the train has come to a stop, or the danger is passed.

Question 110. Would it not be better to return the handle to lap position after a quick reduction has been made? The object to save brake-pipe pressure to assist in releasing?

Answer. No. The first consideration in a case of emergency is to stop and to do that as quickly and surely as possible. The handle should be left in emergency position.

Question 111. If the motorman has the brake partially applied with service application and should be suddenly flagged, what should he do?

Answer. Put the valve handle in the emergency position and leave it there until stopped, the same as before.

Question 112. Would he get quick action under those circumstances?

Answer. That depends on the amount of reduction made in service and the length of the piston travel. With only a slight reduction he would get partial quick action, but would not get full quick-action brake-cylinder pressure.

Question 113. Could anything be gained by placing

the handle in release position for a moment before going to emergency position?

Answer. No; it would be dangerous to do so. Such an action would release the brakes when they were most needed and would make them slower to apply.

Question 114. If the motorman had the brakes applied with a thirteen to fifteen-pound service application, and was flagged, would it be policy for him to put the brake-valve in the emergency position?

Answer. Yes; if it were a case of emergency. Possibly some of the brakes have partially leaked off; the emergency application would set them fully.

Question 115. In the case of emergency should a motorman reverse his motors?

Answer. Yes. As a last resort to prevent collision or to save life he may reverse his motors. Handle on master controller should be thrown into opposite direction to the first, or switching notch, which notch is usually found to have the greatest retarding effect. Motors may also be reversed in the event of brakes being inoperative, but in ordinary service conditions motormen must never reverse motors.

Question 116. In case the brakes are applied suddenly from the train, what should the motorman do?

Answer. Place the brake-valve handle on lap position until a signal is given to release the brakes.

Question 117. Why is this done?

Answer. To maintain the main reservoir pressure and to prevent its escape, thereby providing for a prompt release of the brakes.

Question 118. How should the conductor's valve be operated when necessary?

Answer. It should be pulled wide open and allowed to

remain or be held in that position until the train stops, and then before leaving it the valve should be closed.

All cars have a conductor's valve which, when opened, remains in that position until closed by hand.

Question 119. Why is it necessary to leave the conductor's valve open until the train has stopped, if it is used?

Answer. Because if it is closed and the motorman fails to place the brake-valve on lap position the brakes will release.

Question 120. What does this valve do when it is open?

Answer. It makes a direct opening from the brake-pipe to the atmosphere, the same as when the brake-valve is placed in the emergency position.

Question 121. Can the brakes be released with the conductor's valve?

Answer. No. It must be remembered that to release brakes it is necessary to either put air into the brake-pipe or take it out of the auxiliary reservoirs. The conductor's valve will not do either of these.

Question 122. Should the brake apply suddenly, without the aid of the motorman or train crew, what should be done?

Answer. Place the brake-valve handle on the lap position as before.

Question 123. What would be the probable cause of this?

Answer. Either a burst hose, burst brake-pipe, or train breaking in two.

Question 124. In the event of a burst brake-pipe hose, what should be done?

Answer. Close the flat handled cut-out cock imme-

diately ahead of the burst hose and release the brakes back of the burst hose by closing the double cut-out cocks and opening the bleed cocks in the auxiliary reservoirs, leaving them open. The brakes ahead of the fractured hose can be released, provided the brake is still operative upon at least half of the cars in the train. If the motorman has control of less than half of the brakes of the train, the hand brakes on the cut-out cars must be applied to assist in controlling the train.

Question 125. In the event of a control-pipe hose bursting, what should be done?

Answer. Close the round-handled cut-out cocks immediately ahead and behind of the disabled hose, the brakes may then be operated in the usual manner until the train reaches the terminal, when the fractured hose must be replaced.

Question 126. Should the cross-over pipe connecting the brake-pipe and triple valve be broken, what should be done?

Answer. If the break is between the double cut-out cock and the triple valve, the double cut-out cock should be closed and the release valve opened under the disabled car. If the pipe is broken between the double cut-out cock and the brake-pipe, the flat-handled cut-out cock on the front end of the disabled car should be closed, release valves in all auxiliary reservoirs behind disabled car, as well as on that car opened, and the brakes operated the same as with the burst hose.

Question 127. If the brake pipe should be broken or burst, what should be done?

Answer. Close the cut-out cock on the front end of the car and operate brakes as per Answer 124.

Question 128. In setting off cars, what should be done?

Answer. The cut-out cocks should be closed first and the hose parted by hand and hung up properly.

Question 129. Should the hand-brake be set before releasing the air-brake?

Answer. No.

Question 130. What is the proper way to release a brake with a bleed cock?

Answer. The bleed cock should be held open until the exhaust air commences to escape from the triple valve; it should then be closed, as, if it is held open longer, it results in waste of air and has a tendency to set the other brakes.

Question 131. When it is permissible to cut out brakes on cars?

Answer. Only when they are in such condition to render it impossible to operate the brakes on such cars.

Question 132. Are small leaks sufficient cause for cutting out cars?

Answer. No.

In Fig. 535 is given the arrangement of the apparatus on a motor car of the West Jersey and Seashore R. R. Fig. 536 shows a slightly different arrangement of the apparatus on the motor cars of the New York Central.

The wiring of the apparatus is the same in both roads, and is proven by Fig. 537.

The arrangement of apparatus on the locomotives of the New York Central is shown by Fig. 538, and the wiring diagram in Fig. 539.

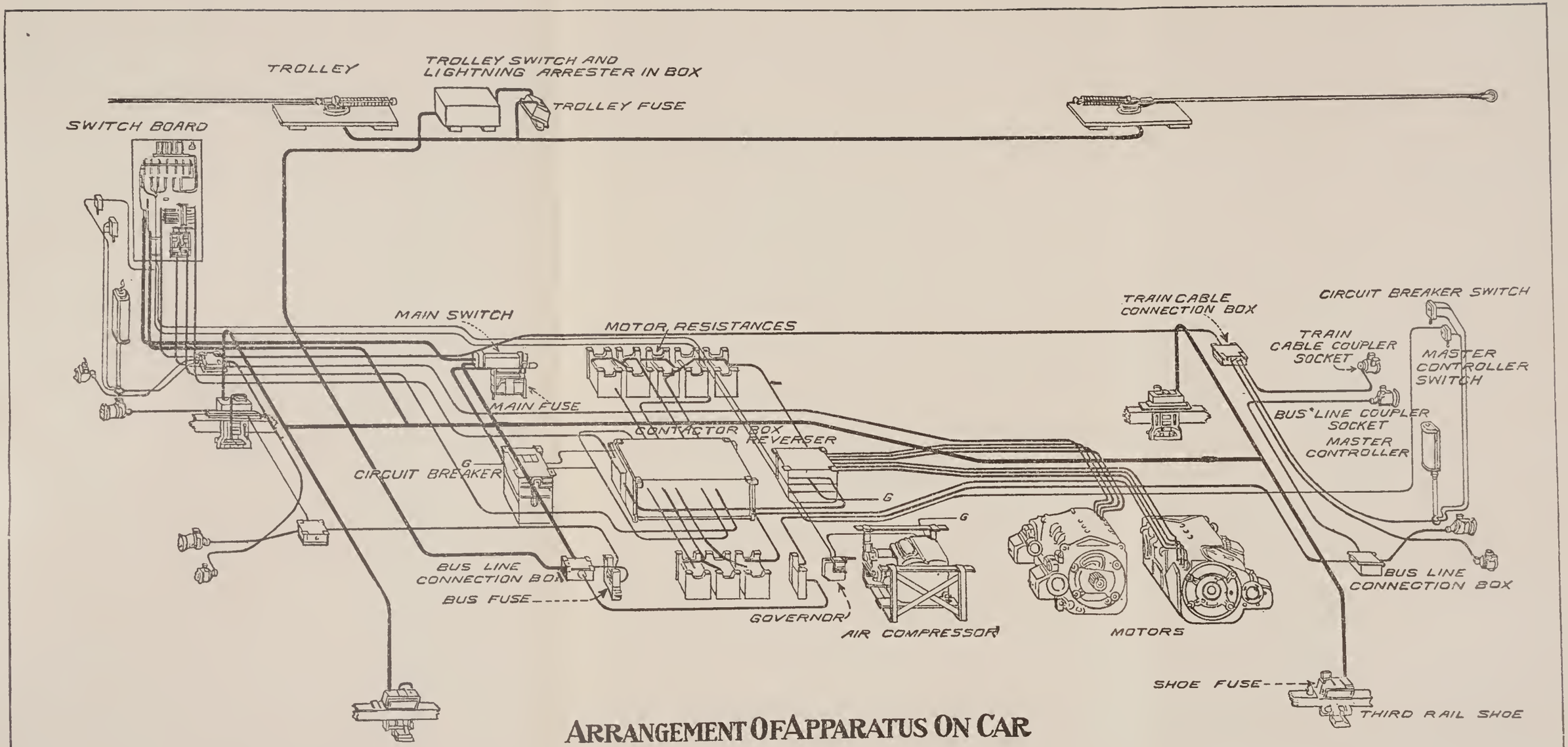
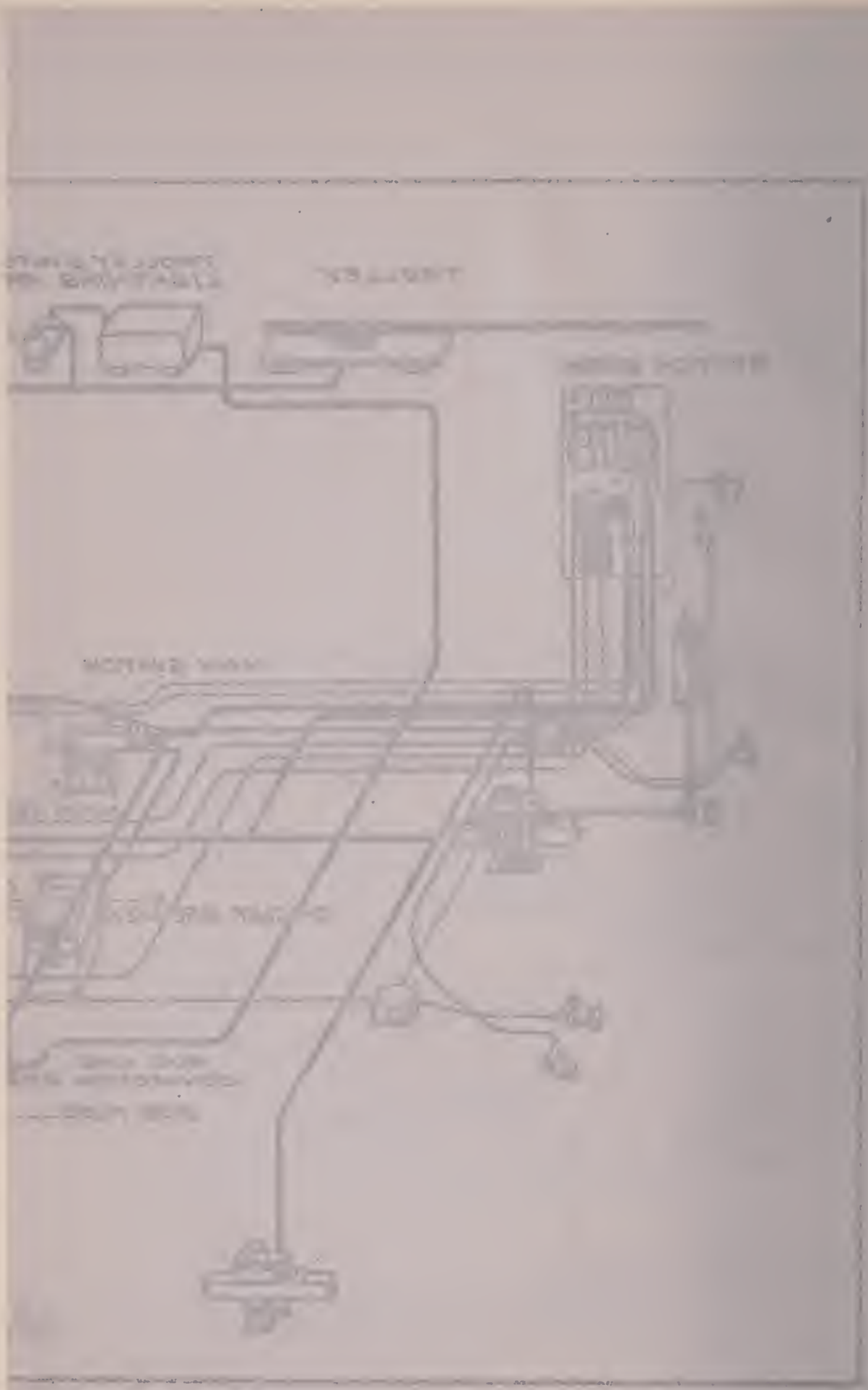
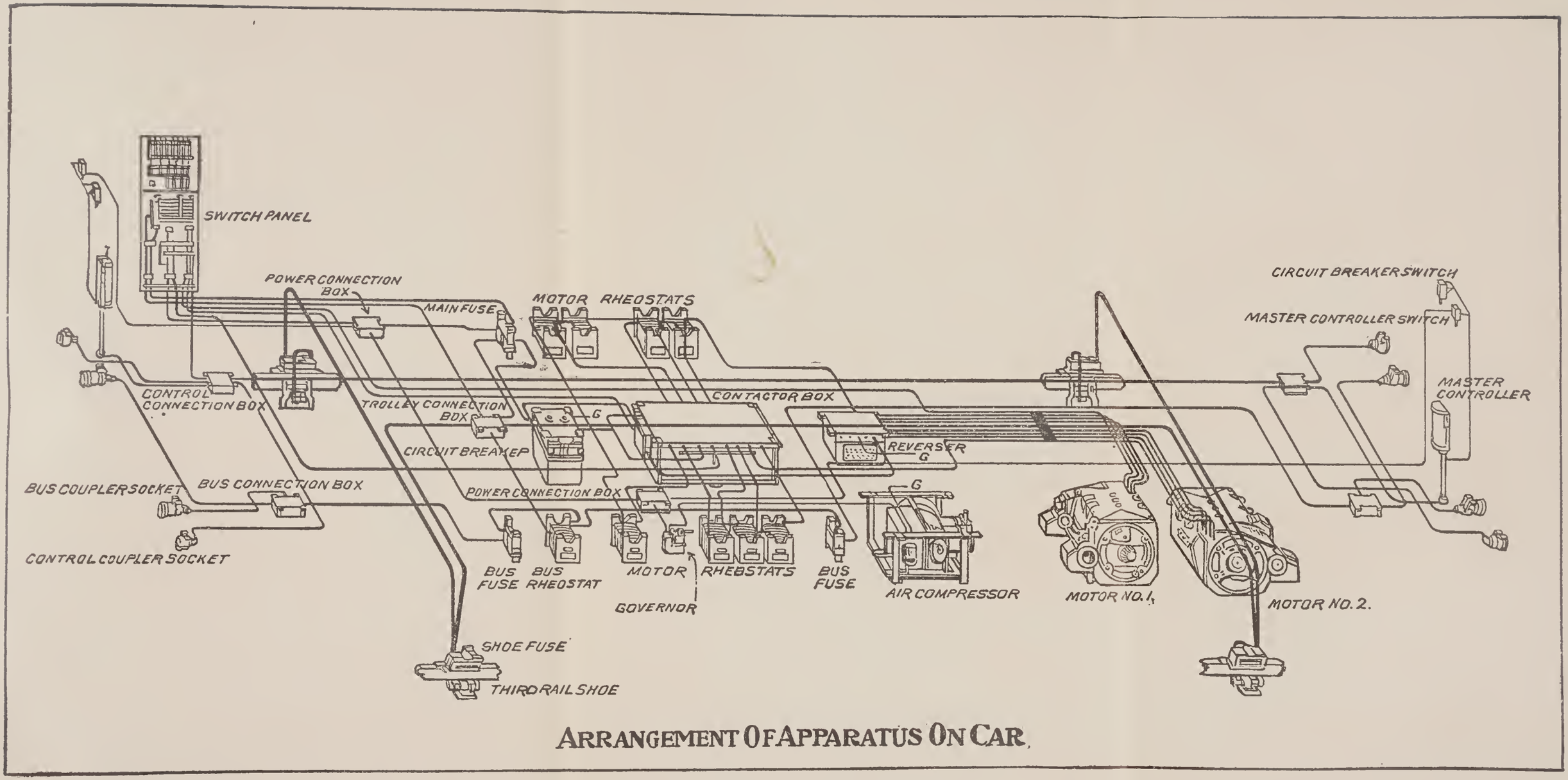


Fig. 535. Pennsylvania Equipment.





ARRANGEMENT OF APPARATUS ON CAR.

Fig. 536. New York Central Equipment.

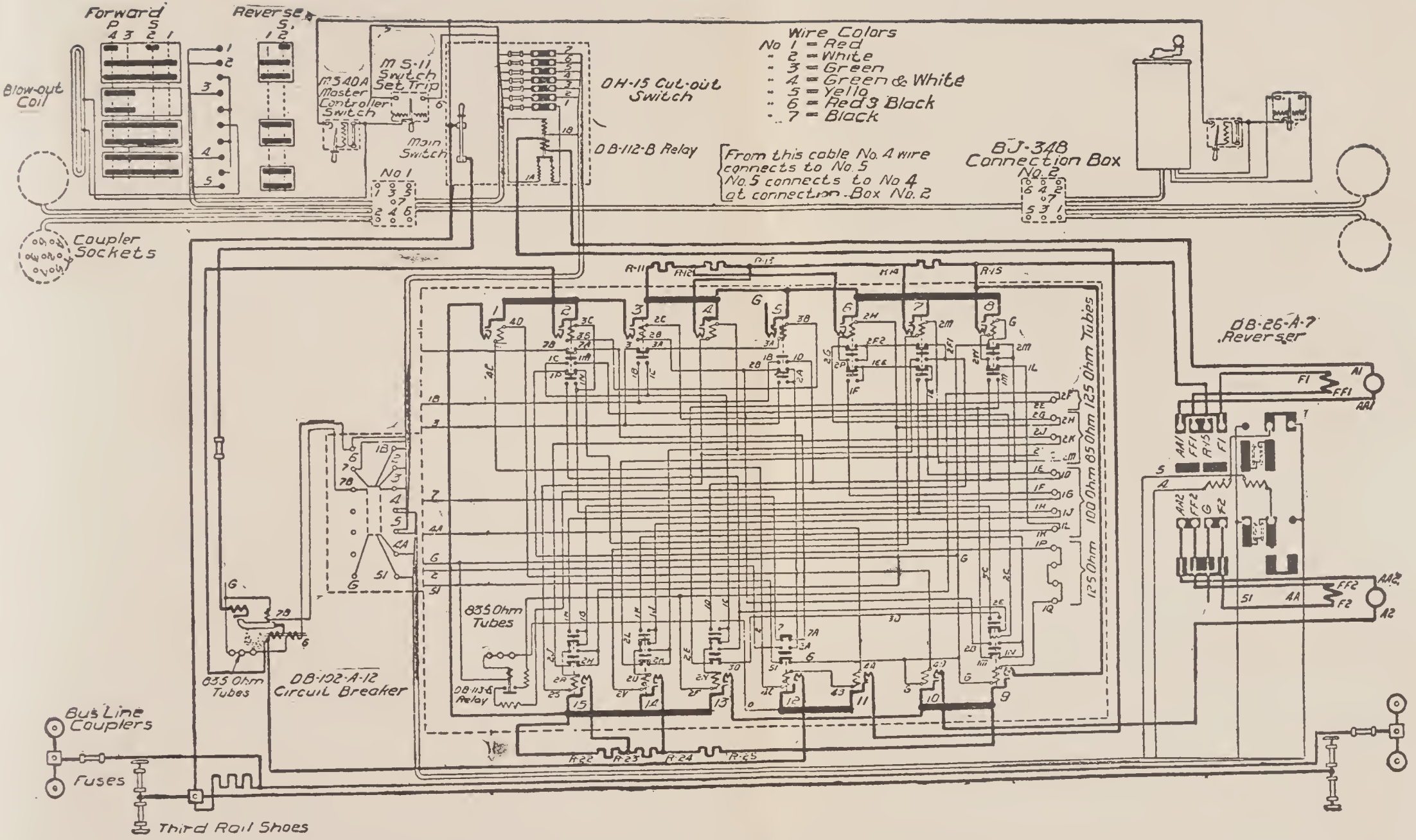
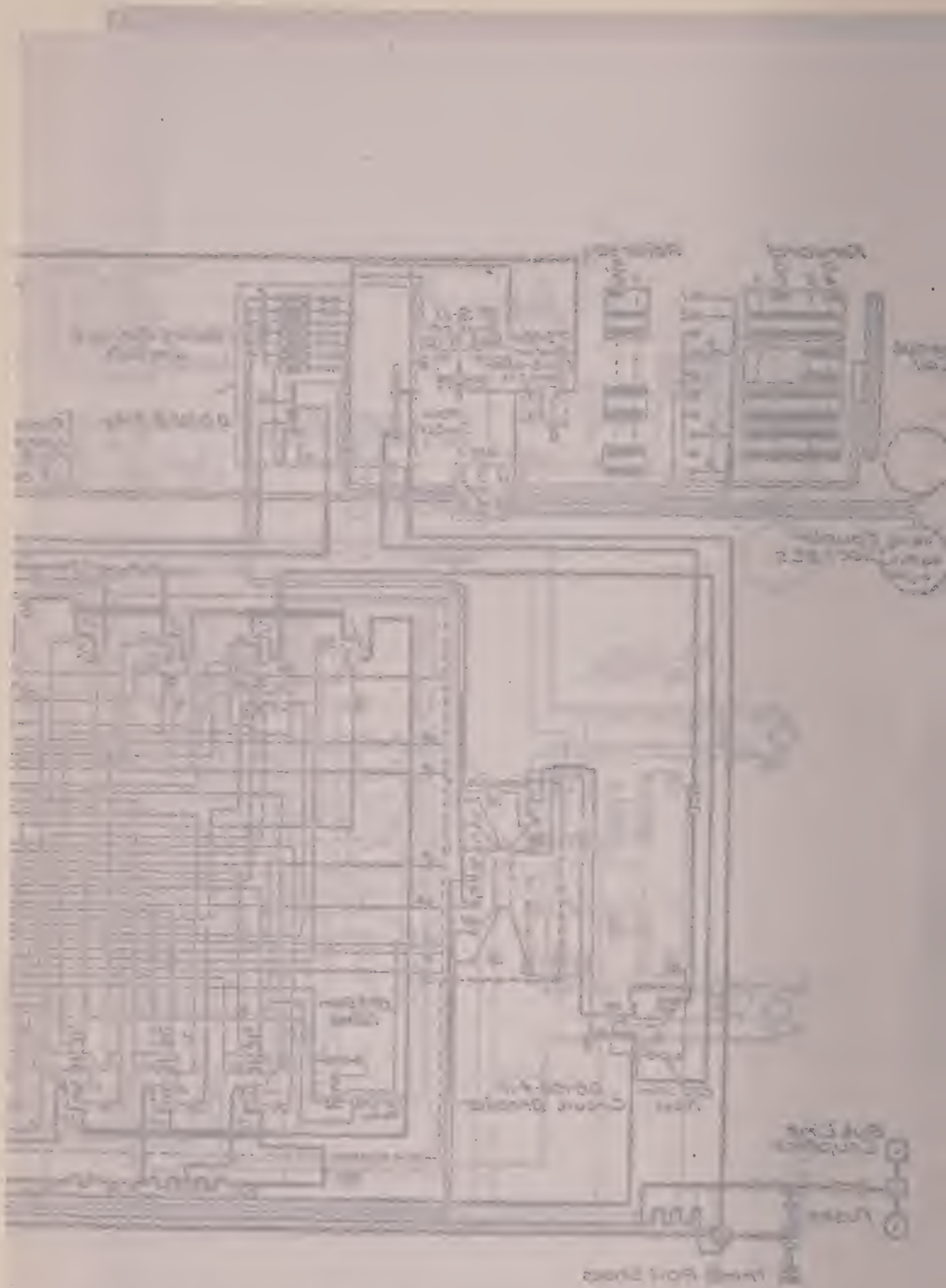


Fig. 537. Wiring Diagram. New York Central Motor Car.



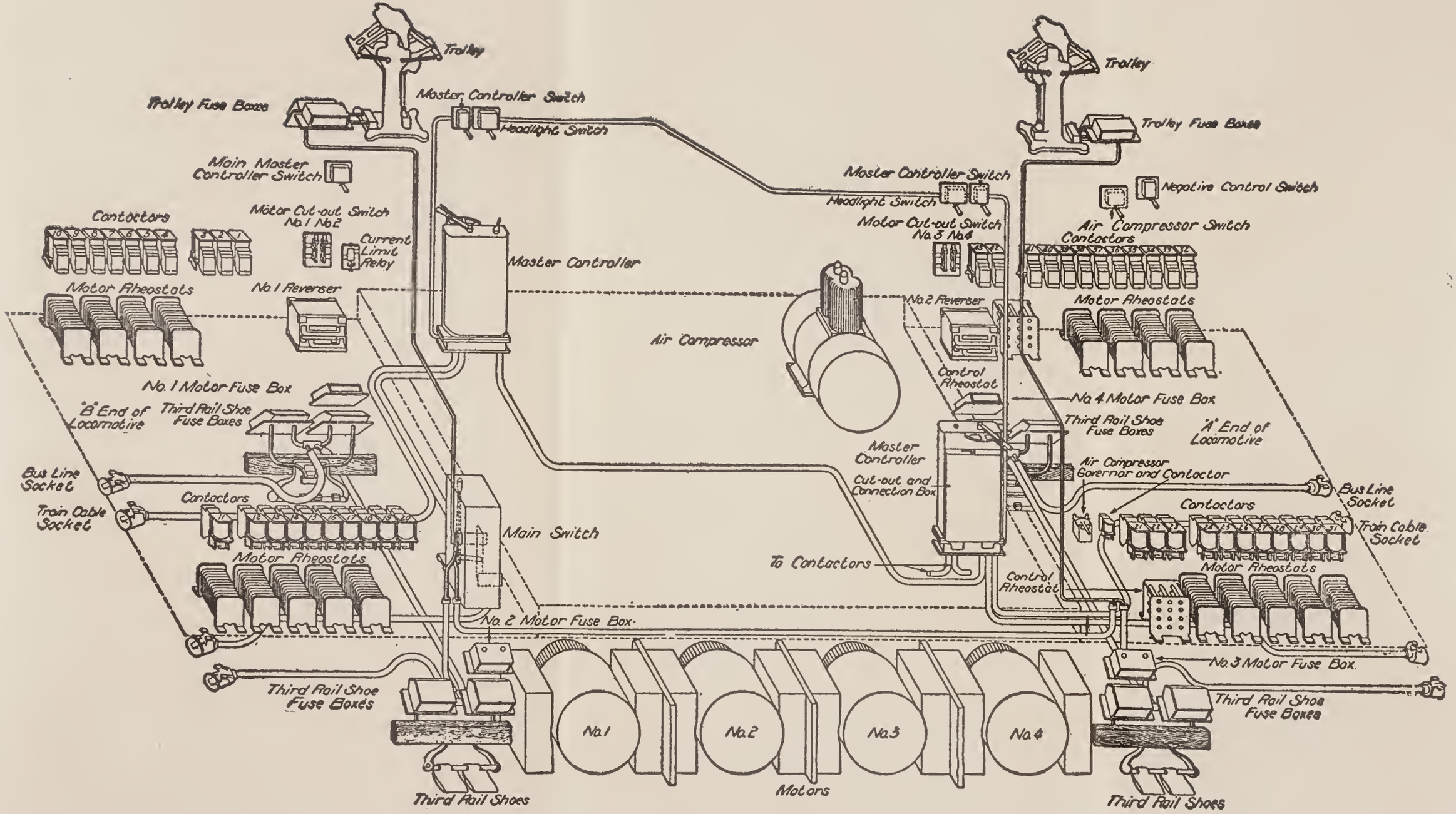
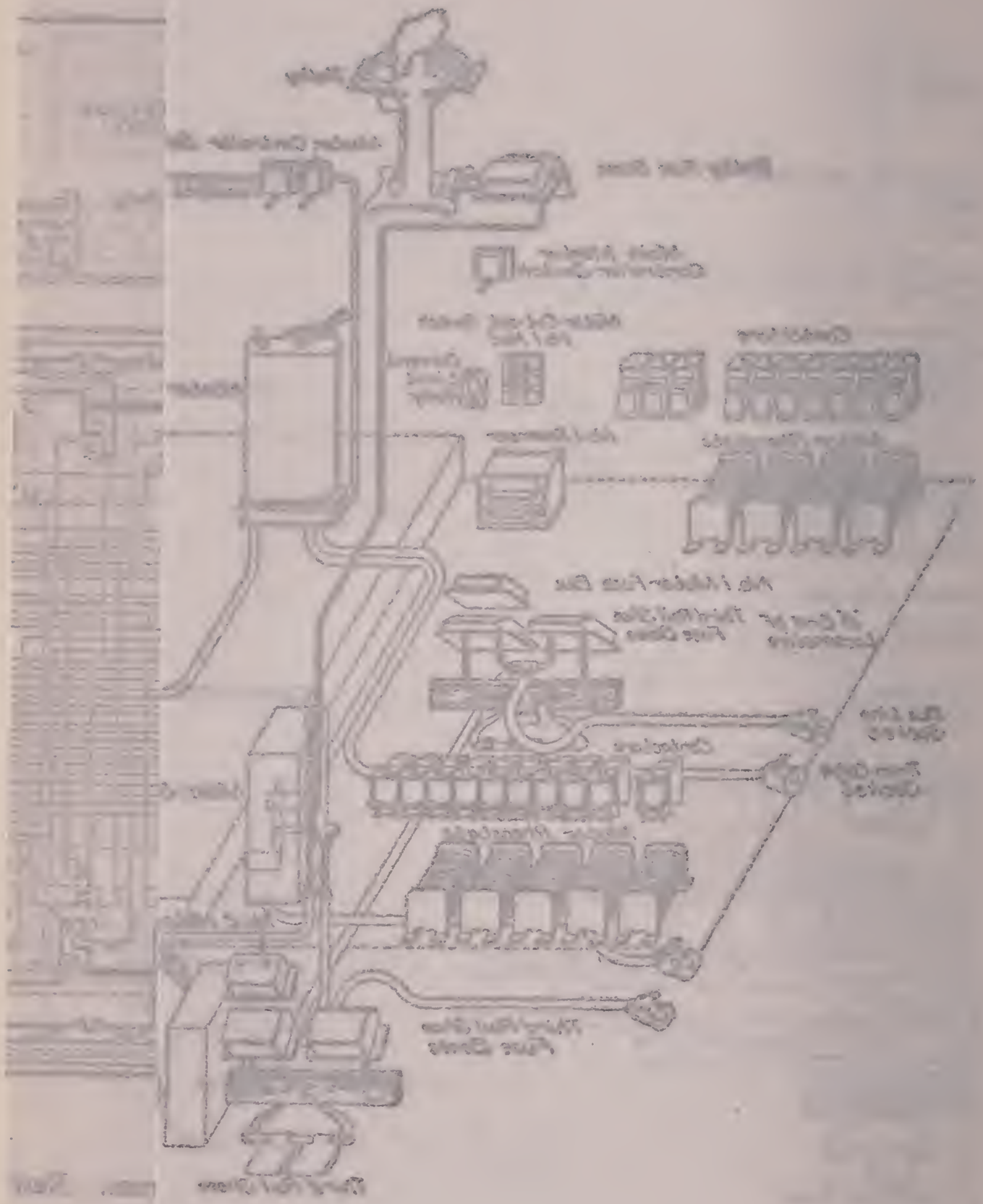


Fig. 538. Arrangement of Apparatus on Locomotive.



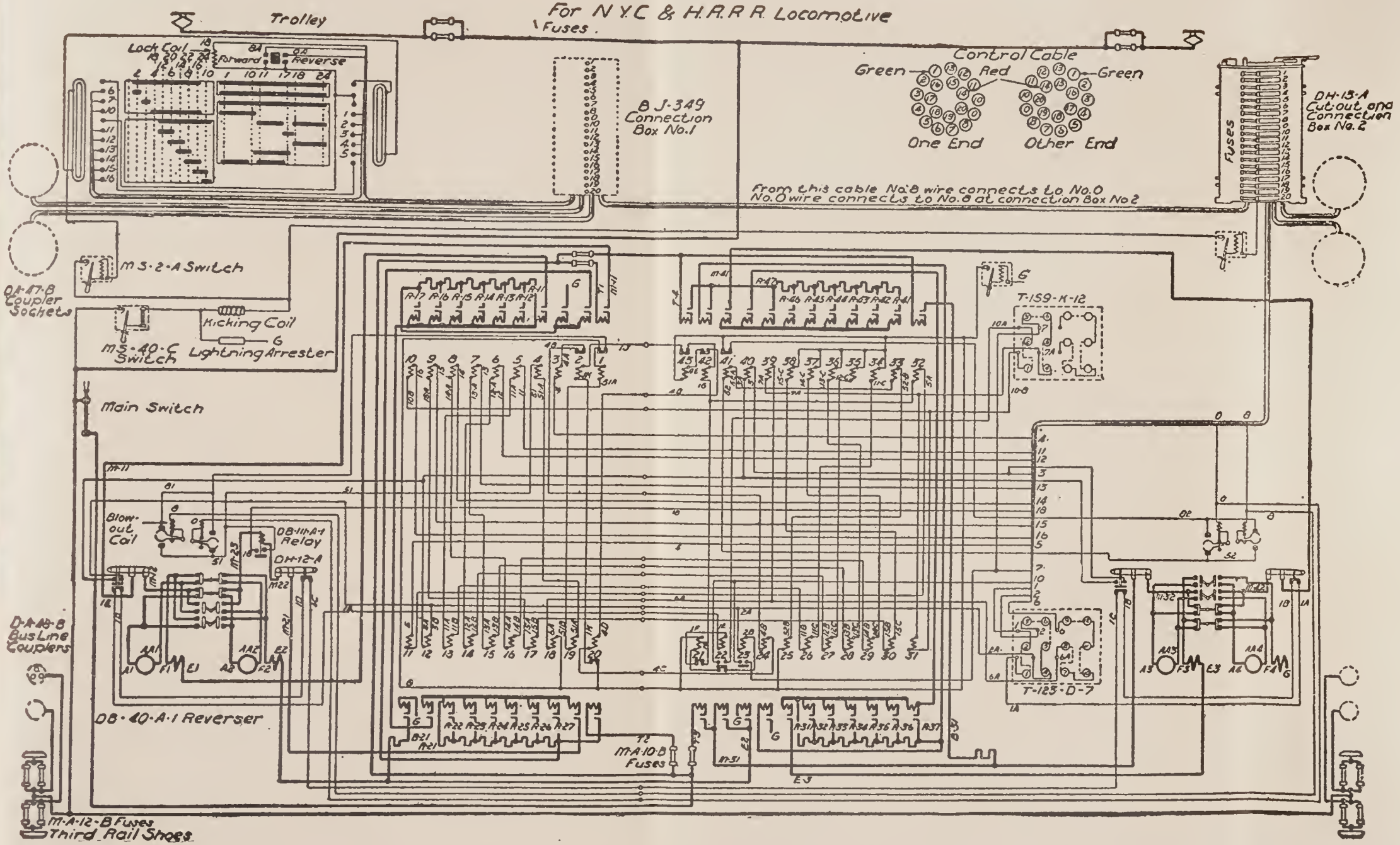
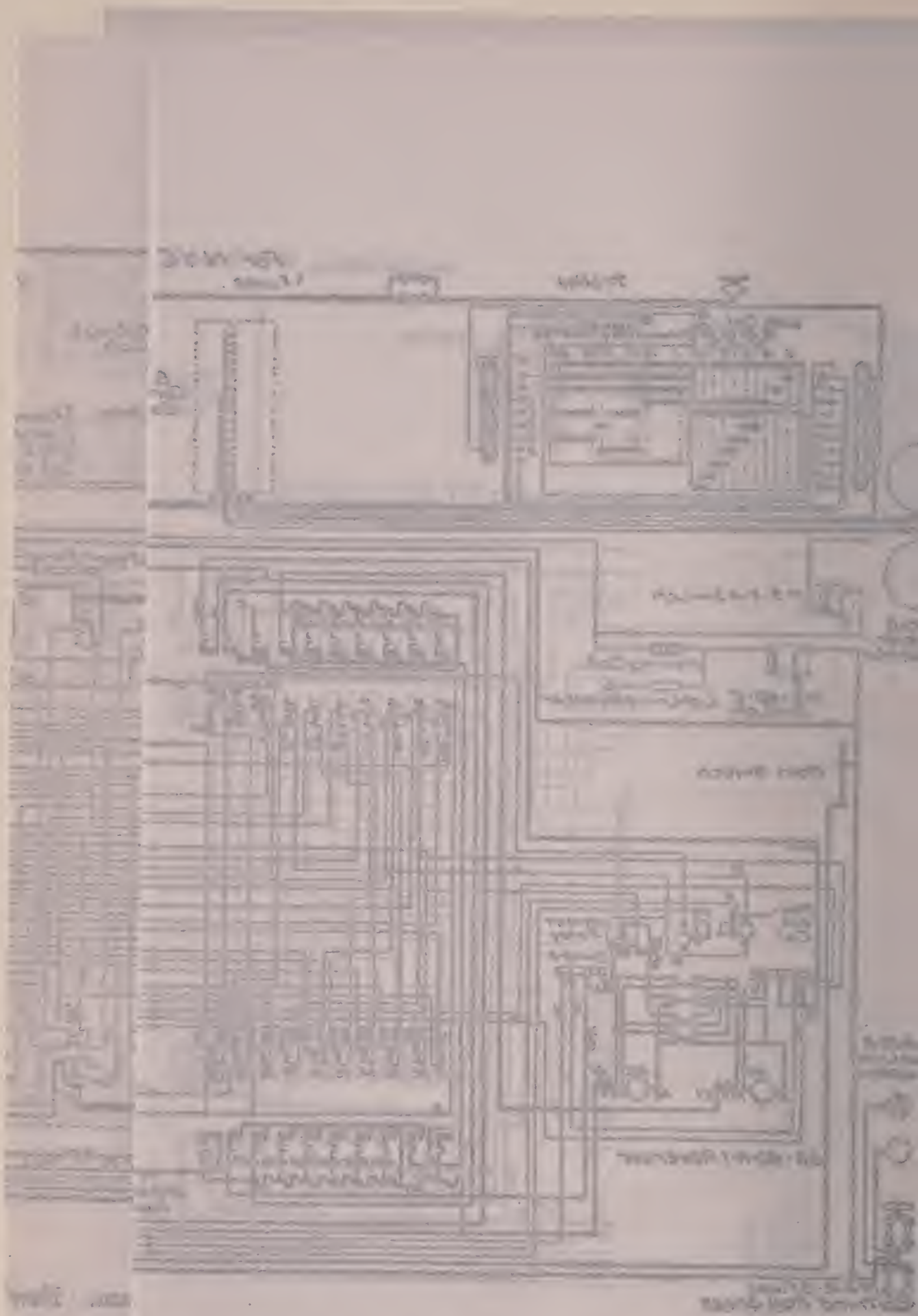


Fig. 539. Wiring Diagram. New York Central Locomotive.



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